Fishery Data Series No. 12-06

Analysis of Red King Crab Data from the 2011 Alaska Department of Fish and Game Trawl Survey of Norton Sound

by

Joyce Soong

and

Toshihide Hamazaki

February 2012

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first 3 letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 12-06

ANALYSIS OF RED KING CRAB DATA FROM THE 2011 ALASKA DEPARTMENT OF FISH AND GAME TRAWL SURVEY OF NORTON SOUND

by
Joyce Soong
Alaska Department of Fish and Game, Division of Commercial Fisheries, Nome
and
Toshihide Hamazaki
Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

February 2012

This investigation was partially financed by Cooperative Agreement NA03NMF4370188 from the National Oceanic and Atmospheric Administration. The views expressed herein are those of the authors and do not reflect the views of NOAA or any of its subagencies.

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/ This publication has undergone editorial and peer review.

Joyce Soong,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
103 E Front Street, Nome, Alaska 99762 USA

and

Toshihide Hamazaki,
Alaska Department of Fish and Game, Division of Commercial Fisheries
333 Raspberry Road, Anchorage, Alaska, 99518 USA

This document should be cited as:
Soong, J., and T. Hamazaki. 2012. Analysis of red king crab data from the 2011 Alaska Department of Fish and Game trawl survey of Norton Sound. Alaska Department of Fish and Game, Fishery Data Series No. 12-06, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

A trawl survey was conducted in Norton Sound in northwest Alaska to collect and analyze information on the distribution and abundance of demersal fishes and invertebrates from July 18 through August 15, 2011, with primary focus on red king crab *Paralithodes camtschaticus*. Population estimates were generated using an area-swept method as calculated in previous trawl surveys of Norton Sound. Legal male abundance was estimated at approximately 1.31 million crabs, equivalent to a biomass estimate of 3.67 million pounds. The 2011 trawl survey biomass estimate is 161% of the 2008 estimate and is 126% of the long-term trawl survey average. Prerecruit-1 male abundance was estimated at approximately 0.312 million crabs, 55% of the 2008 estimate and 50% of the long-term trawl survey average. Prerecruit-2 male abundance was estimated at approximately 0.431 million crabs, 46% of the 2008 estimate, and similar to the long-term trawl survey average.

Key words: Norton Sound, red king crab, *Paralithodes camtschaticus*, trawl survey, abundance, biomass estimate, population estimate, catch sampling, distribution, shell age, species composition.

INTRODUCTION

Norton Sound is located in the Norton Sound Section in the Northern District of the Alaska Department of Fish and Game (ADF&G) Registration Area Q, and includes all waters east of the International Dateline between the latitudes of Cape Romanzof and 66˚N (Figure 1). Commercial fisheries for red king crab *Paralithodes camtschaticus* in Norton Sound occur in 2 seasons: (1) from June 15 through generally September 3 (summer), and (2) through the ice only, from November 15 to May 15 (winter). Although the commercial fishery commenced in 1977, subsistence users who primarily fish through the ice have long harvested red king crabs.

Summer commercial fishery harvests have averaged 500,000 pounds annually, ranging from a high of 3,000,000 pounds in 1979 to a low of 20,000 pounds in 1999. The winter commercial fishery is nominal, averaging about 7,000 pounds annually since 1978.

Population abundance estimates from the trawl survey are evaluated by ADF&G biometricians and incorporated into a length-based model developed by Zheng et al. (1998). This model provides estimates of the legal and sublegal male population sizes. A legal male red king crab is defined as having a carapace width $\geq$ 121 mm (4.75 in) or an approximate carapace length (CL) of 105 mm. The model provides population size estimates for 2 male sublegal crab categories: prerecruit-2 crabs, 76 mm to 89 mm CL, requiring 2 or more molts to reach legal size, and prerecruit-1 crabs, 90 mm to 104 mm CL, requiring one molt to reach legal size. Trawl survey and model population estimates are limited to abundances, because reliable paired weight-length information is not available to estimate biomass. The only available paired weight-length data were collected during trawl surveys conducted on board moving ships, which are susceptible to large errors in weight estimation. Therefore, abundance estimates are multiplied by 2.8 pounds, the average weight of legal male crabs from the summer commercial fishery, to calculate estimated biomasses. Since 1976, red king crab trawl survey biomass estimates for legal males have ranged from 1.6 million pounds in 1996 to 4.8 million pounds in 1999, and have averaged 3.0 million pounds.

Triennial Norton Sound trawl surveys were implemented in 1976. Prior to this time, several investigations provided preliminary information on the distribution and abundance of demersal biota (Andriyashev 1937; Ellison et. al. 1950) including an Atomic Energy Commission assessment survey of demersal fishes and invertebrates of the southeast Chukchi Sea/Norton Sound region (Wilimovsky 1966). From 1976 through 1991, the National Marine Fisheries

Service (NMFS) conducted comprehensive triennial stock assessment trawl surveys of Norton Sound to gather information on the distribution and abundance of demersal fishes and invertebrates (Wolotira et. al. 1977; Sample and Wolotira 1985; NMFS 1982; Stevens and MacIntosh 1986; Stevens 1989 and 1992[1]). Additionally, red king crab summer pot surveys were conducted by ADF&G in Norton Sound in 1980, 1981, 1982, and 1985 to provide annual distribution and abundance as well as preseason information to fishery managers regarding stock size and recruit composition (Powell et. al. 1983; ADF&G 1982a, b; Schwarz 1984; and Brannian 1987).

Due to budget constraints, the Norton Sound area was not surveyed during the NMFS 1994 triennial trawl survey. The 1996 ADF&G trawl assessment was the first survey since the 1991 NMFS survey, and the first ever ADF&G trawl survey of Norton Sound (Blau et. al. 1996; Fair 1997). Since then, ADF&G has conducted trawl assessment surveys in 1999, 2002, 2006, and 2008 (Fair and Brennan 2001; Brennan 2002; Soong and Banducci 2006; Soong 2008). A survey was not conducted in 2005 because of difficulties in chartering a vessel. Starting with the 2006 survey, the Norton Sound Economic Development Corporation (NSEDC) has contributed funding and personnel who enabled a larger area of Norton Sound to be surveyed than had been possible during the previous ADF&G surveys. The purpose of the triennial ADF&G trawl surveys are to provide abundance estimates of the Norton Sound red king crab population, crab recruit class composition, and related biological characteristics, as well as to document benthic species composition in Norton Sound. The 2011 survey added to this historical survey record and employed the same stock assessment methods. Ultimately, information assessed by this project is utilized to determine the size of the legal component of the red king crab population used to set harvest guidelines for the commercial fisheries in the region. This report includes information on the abundance, recruit class composition, biomass, and distribution of the Norton Sound red king crab population from the 2011 survey data.

OBJECTIVES

Prioritized objectives for the 2011 Norton Sound red king crab trawl survey are as follows:

1. Estimate the Norton Sound red king crab population using an area-swept method, and describe the size composition by sex and recruit class.
2. Describe the spatial distribution of the Norton Sound red king crab population and relative abundance of associated marine life. Compare the estimated abundance, size composition, and distribution of current Norton Sound red king crab population with the historical trawl survey record.
3. Collect lengths, weights, and additional biological data from other commercial or potentially commercial species captured: specifically, blue king crabs *Paralithodes platypus*, Pacific halibut *Hippoglossus stenolepis*, Pacific cod *Gadus macrocephalus*, walleye pollock *Theragra chalcogramma*, and yellowfin sole *Limanda aspera.*

[1] Stevens, B. G. 1989. Analysis of crab data from the 1988 NMFS survey of Norton Sound and the northeast Bering Sea. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Unpublished Report. February 1989.
Stevens, B. G. 1992. Results of the 1991 NMFS survey of red king crab in Norton Sound. National Marine Fisheries Service, Alaska Fisheries Science Center, unpublished memorandum to the State of Alaska. May 1992.

METHODS

TRAWL SURVEY

The 2011 ADF&G Norton Sound assessment survey was conducted aboard the chartered *R/V Pandalus* from July 18 through August 15. The nonrandom, systematic station location design used by NMFS in their 6 trawl surveys of Norton Sound and by ADF&G in 1996, 1999, 2002, 2006, and 2008 was also used in 2011. This approach provided a comparable survey pattern for the documentation of marine life in this area. The existing 10 by 10 nautical mile (nmi) grid pattern previously established for Norton Sound, with each grid identified by a station number, was utilized (Figure 2). The centers of each survey station, denoted by latitude and longitude coordinates, indicate where each trawl began within a station (Table 1). The direction of trawl was determined by the skipper based on wind, current, and sea swell conditions.

As in past ADF&G trawl surveys, a 400 eastern otter trawl net, spread by two 1.5 by 2.1 m Astoria "V" doors, was towed such that the sweep length of the footrope was 40 feet, for approximately one-half hour, at approximately 2 knots/hour covering a distance of 1 nmi. A global positioning system (GPS) calculated location and distance towed, and a computerized submersible probe recorded bottom temperatures at 3-minute intervals. Every few evenings these data were downloaded to a laptop computer.

Because of the large area of Norton Sound and time and budget constraints, it was not possible to survey the entire area. Different priorities were therefore assigned to certain areas. The highest priority was to trawl the 37 core stations, not including stations 177, 178, 201, and 205 because past trawls at these rocky-bottomed stations have resulted in torn nets and subsequent small or no trawl catches (Blau et al. 1996; Soong and Banducci 2006). The next priority was to trawl stations in tier 1, not including stations 162, 188, 206, 207, 222, and 223 because again, these stations have rocky bottoms and were deemed to be untrawlable during past surveys (Blau et. al. 1996). Core and tier 1 stations make up standard stations (Figure 2). All Norton Sound trawl survey abundance estimates were standardized in 1998 to provide a reliable database for survey comparisons (Fair 1998). Only crab catch numbers from standard stations were used in abundance estimates, because these were the stations most consistently trawled in past surveys. Therefore, core and tier 1 stations were given the highest priority. The 14 stations in tier 2 and 7 stations in tier 3 were trawled as time permitted.

If a tow resulted in 5 or more legal red king crabs, then that station was resurveyed once more, either immediately or as logistics allowed. Resurveys were towed at the same depth, in close proximity to the initial tow track without crossing it, and at similar distances and times at each respective station.

KING CRAB POPULATION ESTIMATION

Population estimates for red king crabs were generated using the area-swept method, for direct comparison to previous analyses (Alverson and Pereyra 1969). Using the area-swept method, A_j was the total area of the j-th station; a_j was the swept area at the j-th station; and n_j was the number of crab captured at the j-th station. The swept area a_j was computed by multiplying the width of the net mouth opening (0.00658 nmi) by the distance trawled. Abundance $\hat{N}_j$ for the jth station was estimated as:

$$\hat{N}_j = n_j \frac{A_j}{a_j} \quad . \tag{1}$$

Surveyed stations were stratified into single-towed and multiple-towed stations. For single-towed stations, stratum *s*, the total crab abundance, $\hat{N}_s$, was estimated as the sum of estimated station abundances:

$$\hat{N}_s = \sum_j \hat{N}_j \quad . \tag{2}$$

The variance of $\hat{N}_s$ was estimated as:

$$V(\hat{N}_s) = \frac{n\sum(\hat{N}_j - \overline{\hat{N}}_j)^2}{n-1} \quad , \tag{3}$$

where *n* was the number of stations trawled.

For multiple-towed stations, stratum *r*, crab abundance per station, $\hat{N}_{j(r)}$, was estimated as the average abundance of tows for station *j*:

$$\hat{N}_{j(r)} = \overline{\hat{N}}_j \quad . \tag{4}$$

Total crab abundance for stratum *r*, $\hat{N}_r$ was estimated as the sum of estimated station abundances:

$$\hat{N}_r = \sum_j \hat{N}_{j(r)} \quad . \tag{5}$$

The variance of $\hat{N}_r$ was estimated as:

$$V(\hat{N}_r) = \sum_j V(\hat{N}_{j(r)}) \quad , \tag{6}$$

where

$$\mathrm{V}(\hat{N}_{j(r)}) = \frac{\sum(\hat{N}_j - \hat{N}_{j(r)})^2}{n-1} \quad , \tag{7}$$

where *n* was the number of tows at station *j*, and assuming independent estimates for each station.

Total abundance of red king crab was a sum of abundance estimates for the 2 strata:

$$\hat{N} = \hat{N}_s + \hat{N}_r . \tag{8}$$

Assuming independent estimates for the 2 strata, the variance of the estimated total red king crab abundance was estimated as:

$$V(\hat{N}) = V(\hat{N}_s) + V(\hat{N}_r) . \tag{9}$$

Coefficient of variation (CV) was calculated by dividing the square root of variance with the total abundance estimate:

$$C\hat{V} = \frac{\sqrt{V(\hat{N})}}{\hat{N}} . \tag{10}$$

KING CRAB DISTRIBUTION, SHELL AGE, AND SIZE STRUCTURE

All red and blue king crabs from each trawl were sampled for sex, size, legality, shell age, and egg development, if applicable. Total number and weight of each crab species captured was also recorded. Carapace lengths (CL) were measured to the nearest millimeter from the posterior margin of the right eye socket to the midpoint of the rear margin of the carapace (Wallace et. al. 1949). Legal males are defined in regulation as those having a minimum carapace width (CW; including spines) of 121 mm (4.75 in).

Shell-age classes were defined by shell condition according to the following definitions.

Soft-shell: The crab has molted within recent weeks. Exoskeleton is still soft and pliable from recent molt.

New-shell-pliable: The coxa and ventral surface of the exoskeleton are white. The legs are easily compressed when pinched (legs contain little muscle at this time). The exoskeleton is fragile and subject to breakage or puncture. With carapace removed, the gills appear translucent-cream in color. Crabs with this type of shell have had their present exoskeletons for approximately 1–3 months.

New-shell-hard: The coxa and ventral surface of exoskeleton are white. Exoskeletal spines and dactyls are sharp but may show slight wear. The legs are mostly full of muscle, merus not easily compressed by pinching. If carapace is removed, the gills will be a light cream color. Crabs with this type of shell have had their present exoskeletons for 4–12 months. Some crabs show characteristics of both new-shell-hard and old-shell, i.e., coxa rimmed with brown scratches but exoskeletal spines and dactyls are sharp. Because red king crabs found in Norton Sound typically molt in September and October and therefore should start to show wear at the time of the trawl survey, these crabs were classified as new-shell-hard.

Old-shell: The distal portion of the ventral coxa is partially or totally rimmed with brown scratches or dots. Exoskeletal spines and dactyls are worn and typically dull at the tips. The legs are full of muscle and the merus is difficult to compress when pinched. If

carapace is removed, gills are tan in color from fouling microorganisms. Crabs with this type of shell have had their present exoskeletons for 13–24 months.

Very-old-shell: The distal portion of the ventral coxa is continuously rimmed with black scratches or dots. The legs are full of muscle and the merus is difficult to compress when pinched. The tips of the dactyls are worn round and black. If the carapace is removed, gills appear dark gray or dark gray-brown in color from fouling microorganisms. Crabs with this type of shell have had their present exoskeletons more than 24 months.

It should be noted here that a different method was used to determine female crab maturity compared to years prior to 2006. In previous reports, adult females were defined as ≥ 72 mm CL or had matted pleopodal setae or egg clutches, while juveniles were defined as < 72 mm CL with clean pleopodal setae. This method was based on the statistical probability that 50% of female crabs will be mature at ≥ 72 mm CL. In 2006, 2008, and 2011, instead of CL, female maturity was determined by examining the extent of development of the abdominal flap (Donaldon and Byersdorder 2005).

CATCH SAMPLING

As the net was retrieved, all species, including fishes and crabs, were shaken from the intermediate portion of the net down to the codend. Once the codend was on board, a boom was used to lift and weigh the codend using a crane scale. The contents of the trawl were then emptied on deck, and the tare weight of the net section originally weighed was reweighed and recorded to calculate the net haul weight.

The trawl catch was then sorted for large debris and large fish. Besides king crab, all Pacific halibut, large walleye pollock and large Pacific cod were retrieved from each haul before subsampling so that accurate numbers of these commercially valuable species were recorded and their mortality reduced. Other large fish of potential commercial value, such as yellowfin sole, were also retrieved and their data recorded as time allowed. Number, total weight, and individual lengths (snout tip to end of tail, in mm) were recorded before returning these species to the sea. The combined weight of these species and large debris were subtracted from the net haul weight to get the adjusted haul weight.

While 2 crewmembers recorded measurements from king crab and large fish, other crewmembers filled 2 or 3 baskets from the remaining haul and shoveled the rest overboard. The combined weight of the sampling baskets was recorded, then the contents were separated to the lowest taxon, and any additional debris (sticks, rocks, etc.) removed. Each taxon was counted, weighed, assigned a NMFS species code, and recorded.

Total catch weight $\hat{W}_{i,j}$ of *i*-th taxon on *j*-th tow was estimated as:

$$\hat{W}_{i,j} = w_{i,j} \frac{T_j}{t_j} , \quad (11)$$

where $w_{i,j}$ is the subsample weight of *i*-th taxon on *j*-th tow, T_j is the adjusted haul weight, and t_j is the subsample weight.

Catch per unit effort (CPUE: kg/km^2) for each tow was calculated as:

$$CPUE_{i,j} = \frac{\hat{W}_{i,j}}{a_j},$$

where a_j was the swept area at the j-th station.

All data were checked for accuracy and entered as time allowed into MS Excel[2] spreadsheets on a laptop computer. Completed stations were emailed daily to the ADF&G office in Nome. Digital cameras were used to photograph survey activities and various species.

RESULTS

TRAWL SURVEY

The 2011 trawl survey was successful. Weather conditions and rough seas prevented trawling on 3 separate days, and twice, trawling was cut short because the net suffered a huge tear and had to be repaired or switched out. But with careful monitoring of the sea current direction and bottom topography, the skipper of the vessel was able to, in daylight hours between July 18 and August 15, successfully complete 70 tows out of 71 attempts in Norton Sound (Table 2). Stations 104, 122, 132, 185, and 186 were retowed because 5 or more legal crabs were caught. One station (180) was retowed because in the original tow the net was extensively damaged and had a small catch. The net was torn at several additional stations by a hard bottom, but the distances trawled were still at least 0.7 nmi each and the haul sizes were not noticeably smaller. Seven stations were not trawled in 2011 that had been trawled in past ADF&G surveys due to bottom substrate that were likely to cause extensive damage to the nets. Stations 177, 178 and 205 were not trawled because they have never been successfully trawled. Stations 162, 188, 206, 207, 222, and 223 have never been trawled by ADF&G because they have a rocky substrate and are unsuitable for trawl gear. All resampled stations (due to number of legal crabs) were successfully resurveyed immediately after the original surveys.

The average distance towed was 1.0 nmi and the average trawl depth was 9.9 fathoms, ranging from 3.6 fathoms at stations 220 to 19.2 fathoms at station 205 (Table 1).

Bottom temperatures for all tows ranged between 4.6˚C and 13.3˚C. The coldest temperature occurred at station 82, which is in the southwest corner of the trawled area, while the warmest temperature occurred in northeast Norton Sound at station 220, which was also the shallowest station (Table 1; Figure 3).

KING CRAB POPULATION ESTIMATION

Some trawls were conducted in stations in tiers 2 and 3, which were outside of the standardized zone defined in Fair (1998). Crabs caught in these 15 nonstandard stations were excluded from population estimates. Both male and female crabs were captured in tiers 2 and 3 stations. The legal population estimate from the 7 nonstandard stations, in which 50 crabs were caught, was 390,012 crabs, an increase of 83% from 2008 (Figure 4). The prerecruit-1 male catch from the nonstandard stations was 17 crabs (Figure 5), yielding a population estimate of 136,779 crabs, an increase of 200% over 2008. Lastly, 5 prerecruit-2 male crabs were captured at nonstandard stations (Figure 6) for a population estimate of 45,593 crabs, a decrease of 40% from 2008.

[2] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

In the standardized zone, legal male catch was much higher in 2011 than in 2008; however, prerecruit-1 and prerecruit-2 male catches were lower (Table 3). Number of male crabs caught was: 123 legal, 29 prerecruit-1, and 40 prerecruit-2. The estimated abundance of legal male red king crabs was 1,310,634 crabs with a corresponding biomass of approximately 3.67 million pounds, up 61% from the 2008 legal male abundance estimate of 811,727 crabs (Table 3). For legal male abundance estimates, the CV was 10% in 2011, compared to 13% in 2008. The estimated abundance for prerecruit-1 males was 311,550 crabs, and for prerecruit-2 males, it was 431,153 crabs. The 2011 prerecruit-1 male abundance estimate was down 55% from the 2008 abundance of 697,442 crabs. The prerecruit-2 male abundance estimate was also much less than the 2008 prerecruit-2 abundance, by 46%. A female abundance estimate was not generated, but the female catch of 123 crabs (Figure 7) was 134% of the 2008 survey.

Similarly to 2008, the 2011 trawl survey provided resurvey catch information that could be used for replicate abundance estimation with a corresponding variance between surveys for each retowed station (Appendix A1). Each of the 5 resurveyed stations captured legal males in both tows.

KING CRAB DISTRIBUTION, SHELL AGE, AND SIZE STRUCTURE

The 2011 distribution of female red king crabs changed slightly from the 2008 survey. Females were most abundant slightly southeast of Nome (station 183) and in the central portion of Norton Sound (stations 158 and 129) in 2008, while in 2011 (Figure 7), they were most abundant in an area south of Nome that encompassed 3 stations (stations 183-185) and in the central portion of the Sound (station 154). The distribution of male red king crabs shifted more greatly than the females. In both 2008 and 2011, higher abundance of male crabs were found in an area south of Nome that encompassed 4 stations (stations 183-186), but only in 2011, legal males and prerecruit-ones were also found in high abundance in eastern Norton Sound, east of the standardized zone (station 122; Figures 2 and 4–6).

The size composition of male crabs (n=395) caught during the 2011 Norton Sound trawl survey consisted of 56.2% prerecruits, 19.5% recruits, and 24.3% postrecruits, ranging in size from 30 mm to 138 mm CL (Figure 8). Slightly more than two-thirds of the legal crabs captured (n=173) were new-shelled (Figure 9), compared to 95% of sublegal crabs (n=222) which were new-shelled (Figure 10). The size composition of legal males from the 2011 trawl survey was very similar to that found in the 2011 winter pot study (n=335). On the other hand, size composition of the 2011 summer commercial fishery had a greater percentage of larger crabs (n=2,552; Figure 11), due to the fact that even though minimum legal size is CW of 121 mm (4.75 in), the marketable size is ≥ CW of 127 mm (5.00 in), or an approximate CL ≥ 105 mm.

Female catch consisted of 45% adults (n=61) and 55% juvenile crabs (n=74; Table 4). Of the adults, 36 (or 59%) had relatively full (≥ 60%) egg clutches. The majority of the clutches were purple colored, indicating recent extrusion, and all clutches were uneyed.

CATCH COMPOSITION

There were 121 taxa identified in 2011, compared to 113 in 2008. Based on CPUE (weight caught per area trawled), the 5 top-ranking taxa in decreasing order consisted of the purple-orange sea star (*Asterias amurensis*), black-spined sea star (*Lethasterias nanimensis*), saffron cod (*Eleginus gracilis*), starry flounder (*Platichthys stellatus*), and unidentified sponge (*Porifera*; Table 5). Invertebrate species accounted for 29 of the 40 top-ranking taxa by CPUE.

Unlike in 2008, no blue king crabs were captured during the 2011 survey. Of the large fish captured, there were 19 Pacific halibut with an average weight of 5.4 kg and average length of 700 mm, 1 Pacific cod with a weight of 7.2 kg and length of 896 mm, and one yellowfin sole with a weight of 1.6 kg and length of 440 mm (Table 6). Unlike in 2008, no walleye pollock were caught in the 2011 trawl survey.

DISCUSSION

TRAWL SURVEY

The number of trawl stations completed in 2011 was fewer than in 2008; however, due to the higher number of retows, the number of successful tows completed in 2011 was higher than in 2008 (Table 2). Of the 16 stations not sampled, 8 have never been trawled successfully. Stations in the core and tier 1 areas that had been previously trawled but not during 2011 were stations 201 and 204 because these stations were deemed untrawlable by the skipper of the *R/V Pandalus*. The remaining untrawled 6 stations were all in tier 2 along the coast of eastern Norton Sound. Trawling at most of these stations in 2008 had caused extensive net damage; therefore, due to limited net gear and probable net damage, these stations were not trawled in 2011.

All 6 ADF&G Norton Sound trawl surveys (1996, 1999, 2002, 2006, 2008, and 2011) were similar; however, they differed from previous NMFS surveys in design and trawl gear. The total area surveyed in Norton Sound in 1976, 1979, and 1982 was slightly larger than the area surveyed from 1985 to the present. The trawl net used on all 6 NMFS surveys in Norton Sound from 1976 to 1991 was an 83-112 eastern trawl net, whereas ADF&G used a 400 eastern trawl net. The 83-112 eastern net has a similar footrope configuration to the 400 eastern and tows similarly over rough bottom; therefore, it is unlikely that large catch selectivity differences exist between the 2 nets (Robert Otto, NMFS, personal communication to Lowell Fair, Commercial Fisheries Biologist, 1996).

KING CRAB POPULATION ESTIMATION

The 2011 trawl survey results showed an increase in legal population size relative to 2008 (Table 3). The legal population estimate for 2011 was 161% of the 2008 estimate, and was the highest since the 1999 survey, which showed a record abundance estimate for legal male crabs. Notably, compared with 2008, legal crab was caught not only at higher numbers, but also in a wider range. For instance, in 2008, legal crabs were caught at 19 out of 48 trawled stations, whereas in 2011 they were caught at 29 out of 49 trawled stations. For both prerecruit-1 and prerecruit-2 male abundance, the 2011 estimates were roughly half of the corresponding estimates from 2008. It should be noted, however, that prerecruit-1 estimate increased 2-fold outside of the standardized zone, which suggests that the observed decline is partially due to changes in distribution. The major difference with the previous survey is that the 2011 survey did not find high concentrations of prerecruit-1 and prerecruit-2 crabs at stations 183–186 and 159. In 2008, 34 prerecruit-1 and 38 prerecruit-2 crabs were caught in those stations (Soong 2008), but this year only 11 prerecruit-1 and 23 precruit-2 crabs were caught at the same stations. Prerecruit-1 and prerecruit-2 crabs will molt over the next 2 years and contribute to the legal portion of the population in 2012 and 2013. Results from the 2011 Norton Sound winter pot study (Josh Mumm, Commercial Fisheries Biologist, ADF&G, Nome;[3]) show that the steady increase in proportion of legal males seen from 2007 through 2010 has leveled off, with

[3] Alaska Department of Fish and Game, Norton Sound winter crab study; information supplied by project leader Josh Mumm.

proportions of all ages this year similar to last year. Taken together, results from the trawl survey and winter study indicate that legal abundance will remain stable in the near future with a possible decrease in 2013.

KING CRAB DISTRIBUTION, SHELL AGE, AND SIZE STRUCTURE

Comparisons in distribution were made only between the 2006, 2008, and 2011 surveys because the number and location of completed stations were the most similar in these years compared to survey years prior to 2006 (Table 2). In 2011, a significant portion of the male crab population appears to have shifted slightly west of the area where they were most abundant in 2008, back to where they were most abundant in 2006. Additionally, the highest abundance was found in eastern Norton Sound, east of the standardized zone, in an area where crabs had not been found in appreciable numbers in the previous 2 trawl surveys. For females, there were slight shifts to the north and to the west for a significant portion of the population found just south of Nome. Another sizeable percentage of the female crab population located in central Norton Sound had shifted slightly to the east and to the north. Except for the high male population found in eastern Norton Sound, the shifts were slight for both sexes, and differences in distribution were to be expected. In general, male crabs have been found in most abundance immediately south of Nome whereas females have been found in greater abundance south of Nome as well as in the central portion of Norton Sound. More studies need to be conducted to explain the higher abundance of male crabs found in eastern Norton Sound in 2011. In 2011 crab size structure showed bimodal with stronger juvenile size class, similar pattern also occurred in 1982 and 1991 (Figure 12); however, similar pattern was not observed during the 2011 winter survey study (Josh Mumm, Commercial Fisheries Biologist, ADF&G, Nome;[1]). This suggests inefficiency of winter crab survey, or trawl survey, by chance, catching exceptionally large proportion of juveniles. Future trawl survey will track the fate of this cohort.

The area-swept method for abundance estimation assumes that catch is proportional to the area physically trawled and to crab density (Ricker 1940; Gulland 1964). This assumption is likely satisfied. The method also assumes crab density in the area physically trawled is representative of the grid section in which a trawl is located. The variance estimator assumes that the probability of a crab being located within the trawl area is equal to the relative size of the trawl area, a uniformity assumption. The validity of these assumptions is difficult to assess. However, distribution of crabs within an area is likely dependent on various factors, such as bottom topography, salinity, temperature, tidal influence, and patterns of seasonal migration. Given the relatively large size of the sampling grid and the project design, these factors have not been fully examined in the context of this trawl survey. The degree to which these factors may bias the estimator is unknown.

FUTURE STUDY

One topic for future study should be an analysis of how different factors such as temperature, topography, and salinity affect king crab migration and distribution. The next Norton Sound trawl survey is scheduled to take place in 2014.

ACKNOWLEDGEMENTS

Special thanks go to the captain and crew of the R/V *Pandalus* who did their best to ensure the survey proceeded as smoothly as possible. The vessel's crew included Captain Mark Hottmann, Robert Hancock, and Fred Woldstad. They were extremely helpful and motivated in all aspects

of our study. We would like to give many thanks to Norton Sound Economic Development Corporation (NSEDC) and their crew in surveying the Norton Sound stations that ADF&G was not able to complete. ADF&G, NSEDC, and vessel survey crews all did excellent work to ensure sampling was done speedily and correctly. Special thanks to Gay Sheffield and the Marine Advisory Program at the University of Alaska Fairbanks Extension for providing photographic and sampling services and to Robert Hancock for counting thousands and thousands of sea stars. Additional thanks goes to Larry Neff for his diligence and expertise in identifying organisms. Thanks also to ADF&G personnel Allegra Banducci, Jenefer Bell, and Katie Howard who assisted with onboard sampling.

REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). 1982a. Westward region king crab survey results for 1982. Division of Commercial Fisheries, Kodiak.

ADF&G (Alaska Department of Fish and Game). 1982b. Annual management report 1982 Norton Sound-Port Clarence-Kotzebue. Division of Commercial Fisheries, Anchorage.

Alverson, D. L., and W. T. Pereyra. 1969. Demersal fish explorations in the northeastern Pacific Ocean. Journal of Fisheries Research Board of Canada 26:1985-2001.

Andriyashev, A. P. 1937. A contribution to the knowledge of the fishes from the Bering and Chukchi Seas. In Russian. Explor. Des mers de l' urss. Fasc. 25, Inst. Hydro. Leningrad, p. 292-355.

Blau, S. F., L. J. Watson, and J. Blackburn. 1996. The 1996 Norton Sound red king crab trawl survey. Alaska Department of Fish and Game, Regional Information Report 4K96-54, Kodiak.

Brannian, L. K. 1987. Population assessment survey for red king crab (*Paralithodes camtschatica*) in Norton Sound, Alaska, 1985. Alaska Department of Fish and Game, Technical Data Report No. 214, Juneau.

Brennan, E. L. 2002. Analysis of red king crab data from the 2002 ADF&G trawl survey of Norton Sound. Alaska Department of Fish and Game, Commercial Fisheries Division, AYK Region, Regional Information Report 3A02-52, Anchorage.

Donaldosn, W. E. and S. C. Byersdorfer. 2005. Biological field techniques for Lithodid Crabs. Alaska Sea Grant College Program, University of Alaska, AK-SG-05-03.

Ellison, J. G., B. Knake, and J. Dassow. 1950. Exploratory fishing expedition to the northern Bering Sea in June and July, 1949. United States Fish and Wildlife Service, Fishery Leaflet 369, Washington, D.C.

Fair, L. F. 1997. Analysis of red king crab data from the 1996 ADF&G trawl survey of Norton Sound. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A97-10, Anchorage.

Fair, L. F. 1998. Standardization of Norton Sound trawl survey red king crab abundance estimates. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A98-36, Anchorage.

Fair, L. F., and E. L. Brennan. 2001. Analysis of red king crab data from the 1999 ADF&G trawl survey of Norton Sound. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A00-26, Anchorage.

Gulland, J. A. 1964. Catch per unit effort as a measure of abundance. Rappt. Proces.-Verbaux Reunions Conseil Perm. Intern. Exploration Mer. 155:8-14.

NMFS (National Marine Fisheries Service). 1982. Cruise results: cruise no. MF-82-3 NOAA R/V *Miller Freeman* (Norton Sound - northeastern Bering Sea crab - groundfish survey). National Marine Fisheries Service, unpublished report. December 1982.

REFERENCES CITED (Continued)

Powell, G. C., R. Peterson, and L. Schwarz. 1983. The red king crab, *Paralithodes camtschatica* (Tilesius) in Norton Sound, Alaska: history of biological research and resource utilization through 1982. Alaska Department of Fish and Game, Informational Leaflet 222, Juneau.

Ricker, W. E. 1940. Relation of "catch per unit effort" to abundance and rate of exploitation. Journal of Fisheries Research Board of Canada 5:43-70.

Sample, T. M., and R. J. Wolotira, Jr. 1985. Demersal fish and shellfish resources of Norton Sound and adjacent waters during 1979. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, NOAA Technical Memorandum NMFS F/NWC-89. October 1985. 208 pages.

Schwarz, L. 1984. Norton Sound section of the Bering Sea 1983 king crab fishery report to the Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Region III: Shellfish Report No. 5, Anchorage.

Soong, J. 2008. Analysis of red king crab data from the 2008 ADF&G trawl survey of Norton Sound. Alaska Department of Fish and Game, Fishery Data Series No. 08-58, Anchorage.

Soong, J., and A. Banucci. 2006. Analysis of red king crab data from the 2009 ADF&G trawl survey of Norton Sound. Alaska Department of Fish and Game, Fishery Data Series No. 06-56, Anchorage.

Stevens, B. G., and R. A. MacIntosh. 1986. Analysis of crab data from the 1985 NMFS survey of the northeast Bering Sea and Norton Sound. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, NWAFC Processed Report 86-16. September 1986.

Wallace, M. M., C. J. Pertuit, and A. R. Hvatum. 1949. Contribution to the biology of the king crab (*Paralithodes camtschatica* (Tilesius)). U.S. Department of the Interior, Fish and Wildlife Service, Technical Report 340:1-50.

Wilimovsky, N. J. 1966. Synopsis of previous scientific explorations. [*In*] N. J. Wilimovsky and J. N. Wolf (editors), Environment of the Cape Thompson region, Alaska, p. 1-5. U.S. Atomic Energy Comm., Wash., D.C.

Wolotira, R. J., Jr., T. M. Sample, and M. Morin, Jr. 1977. Demersal fish and shellfish resources of Norton Sound, the southeastern Chukchi Sea, and adjacent waters in the baseline year 1976. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Processed Report. October 1977. 292 pages.

Zheng, J., G. H. Kruse, and L. Fair. 1998. Using multiple data sets to assess red king crab in Norton Sound, Alaska: length-based stock synthesis. Fishery Stock Assessment Models, Alaska Sea Grant College Program, AK-SG-98-01.

TABLES AND FIGURES

Table 1.–Station location and number of red king crabs captured, by sex and size, during the Norton Sound trawl survey, July 18 to August 15, 2011.

Station Number	Location N. Lat. Deg.	N. Lat. Min.	W. Long. Deg.	W. Long. Min.	Compass Heading (true)	Distance Towed (nmi)	Average Depth (fm)	Bottom Temp. (°C)	Females Juvenile[a]	Females Adult[b]	Males Sublegal 3s[c] (<76)	Males Sublegal 2s[d] (76 mm to 89 mm)	Males Ones[e] (>89)	Males Legal Recruit[g]	Males Legal Postrecruit[h]
78[i]	63	39.73	164	58.35	15	0.80	8.0	8.8	0	0	0	0	0	0	0
79	63	40.08	165	20.60	14	1.00	9.2	7.6	0	0	0	0	0	1	2
80	63	39.83	165	43.43	38	1.00	11.5	7.2	0	0	0	0	0	0	2
81	63	40.50	166	5.41	184	1.00	13.7	6.1	0	0	0	0	0	0	0
82	63	40.25	166	28.34	331	1.00	14.5	4.6	0	0	0	0	0	0	0
94	63	50.67	161	36.07	143	0.81	7.6	9.2	0	1	0	0	0	0	0
95	63	49.99	161	57.52	317	0.86	8.4	7.7	0	1	3	0	0	0	1
96	63	50.12	162	20.55	125	1.00	7.8	9.0	0	6	0	0	0	0	0
97[j]	63	50.05	162	42.83	303	1.00	8.6	8.6	0	0	0	0	0	0	0
98	63	50.80	163	6.87	138	1.00	8.8	8.3	0	0	0	0	0	0	0
99	63	49.69	163	26.36	299	1.00	8.4	8.6	0	0	0	0	0	0	0
100	63	50.00	163	50.46	110	1.00	8.1	8.5	0	0	0	1	0	0	0
101	63	50.11	164	13.09	185	1.00	8.1	9.5	0	1	0	0	0	0	0
102	63	49.97	164	35.52	139	1.00	8.1	9.7	0	0	0	0	1	0	0
103	63	49.70	164	58.61	21	1.00	8.1	8.7	0	0	0	0	0	0	1
104	63	49.67	165	21.25	28	1.00	9.0	7.9	0	0	0	0	0	4	2
104	**63**	**50.09**	**165**	**21.01**	**4**	**1.00**	**9.0**	**8.1**	**0**	**0**	**0**	**1**	**2**	**2**	**3**
105	63	50.30	165	41.56	231	1.00	10.8	na	0	0	0	0	1	1	1
106	63	50.03	166	6.06	306	1.00	13.8	6.5	0	0	0	0	0	1	2
107	63	50.00	166	28.35	311	1.00	16.0	4.9	0	0	0	0	0	0	0
121	64	0.36	161	35.86	107	0.80	9.2	7.3	0	0	0	0	0	0	0
122	64	0.98	161	57.23	166	1.00	8.7	6.3	2	0	0	3	10	15	17
122	**64**	**1.01**	**161**	**57.50**	**175**	**1.00**	**8.6**	**6.3**	**1**	**0**	**2**	**1**	**6**	**9**	**8**
123	63	59.65	162	18.41	313	1.00	8.6	7.7	0	2	1	0	0	2	1
124	63	59.49	162	43.56	54	1.00	9.2	7.0	0	0	0	0	0	0	1
125	63	59.93	163	6.20	83	1.00	9.3	7.0	0	0	2	0	1	1	0
126	63	59.94	163	28.66	84	1.00	9.9	5.8	1	0	1	0	1	1	1
127	64	0.20	163	51.18	113	1.00	9.1	6.6	1	3	1	1	1	1	1
128	63	59.98	164	12.69	107	1.00	8.5	8.5	1	7	1	0	1	1	1
129	64	0.08	164	35.69	144	1.00	9.4	7.5	0	1	0	0	0	0	0

-continued-

Table 1.–Page 2 of 3.

Station Number	Location N. Lat. Deg.	N. Lat. Min.	W. Long. Deg.	W. Long. Min.	Compass Heading (true)	Distance Towed (nmi)	Average Depth (fm)	Bottom Temp. (°C)	Males: Females Juvenile[a]	Males: Females Adult[b]	Males: Sublegal 3s[c] (<76 mm)	Males: Sublegal 2s[d] (76 mm to 89 mm)	Males: Sublegal Ones[e] (>89	Males: Legal Recruit[g]	Males: Legal Postrecruit[h]
130	63	59.93	164	58.41	128	1.00	9.1	8.4	0	0	0	0	2	0	1
131	63	59.94	165	21.85	84	1.00	8.8	7.7	0	0	0	1	0	1	0
132	63	59.59	165	44.20	332	1.00	10.3	na	0	0	0	0	2	4	3
132	**64**	**0.00**	**165**	**44.05**	**332**	**1.00**	**10.1**	**na**	**0**	**0**	**2**	**1**	**0**	**3**	**3**
133	64	0.00	166	6.19	354	1.00	11.6	na	0	0	0	0	0	0	0
134	64	0.02	166	29.09	174	1.00	15.3	na	0	0	0	0	0	0	0
135	63	59.53	166	52.02	174	1.00	17.2	na	0	0	0	0	0	0	0
147[j]	64	10.09	161	9.82	168	0.80	5.6	12.0	0	0	0	0	0	0	0
148	64	10.03	161	32.60	162	1.00	8.4	11.9	0	0	0	0	0	0	0
149	64	9.95	161	55.44	212	1.00	9.0	8.6	0	0	0	0	0	0	0
150	64	10.02	162	17.68	267	1.00	8.4	6.2	0	0	0	0	0	0	1
151	64	9.89	162	32.59	280	1.00	10.7	6.2	0	0	0	0	0	0	3
152	64	10.04	163	3.91	32	0.73	12.5	6.3	3	0	1	1	0	2	0
153	64	10.01	163	26.87	86	1.00	10.0	5.8	0	0	0	0	0	0	3
154	64	9.99	163	49.83	78	1.00	10.1	5.8	9	1	9	0	0	0	1
155	64	10.03	164	12.72	102	1.00	10.0	6.6	0	0	1	0	1	0	1
156	64	10.00	164	35.35	114	1.00	8.0	8.4	0	0	0	0	0	1	2
157	64	9.99	164	58.02	112	1.00	8.0	8.4	0	0	0	0	0	0	0
158	64	10.01	165	21.05	127	1.00	9.0	8.2	0	1	0	0	0	0	0
159	64	9.96	165	43.87	131	1.00	10.1	7.5	0	1	2	0	2	1	2
160	64	9.99	166	6.58	277	1.00	11.6	7.0	0	1	0	1	0	0	2
161	64	9.24	166	29.51	10	1.00	13.9	na	0	0	1	0	0	0	1
175	64	19.97	161	54.83	78	1.00	7.9	10.2	0	0	0	0	0	0	0
176	64	19.18	162	18.60	33	1.00	9.0	11.1	0	9	0	0	0	0	0
179	64	19.22	163	27.95	44	1.00	10.0	9.6	0	1	0	0	0	0	0
180[j,k]	64	20.18	163	49.26	32	0.12	8.9	9.0	0	0	0	0	0	0	0
180	64	19.95	163	49.13	112	1.00	8.8	7.6	3	0	0	0	0	0	0
181	64	20.06	164	12.51	103	0.81	7.0	8.7	0	0	0	0	0	0	0
182	64	20.02	164	35.25	158	1.00	7.5	9.8	0	0	0	0	0	0	0
183	64	19.83	164	57.29	104	1.00	14.8	9.3	7	6	5	3	0	0	1

-continued-

Table 1.–Page 3 of 3.

Station	Location				Compass Heading	Distance Towed	Average Depth	Bottom Temp.	Females		Males				
											Sublegal			Legal[f]	
	N. Lat.		W. Long.								3s[c] (<76 mm)	2s[d] (76 mm to 89 mm)	Ones[e] (>89 mm)		
Number	Deg.	Min.	Deg.	Min.	(true)	(nmi)	(fm)	(°C)	Juvenile[a]	Adult[b]				Recruit[g]	Postrecruit[h]
184	64	19.90	165	21.45	127	1.00	12.1	9.0	13	1	16	9	2	2	1
185	64	20.01	165	44.84	99	1.00	10.7	8.2	9	4	21	5	4	0	6
185	**64**	19.97	**165**	**44.65**	**114**	**1.00**	**10.4**	**8.2**	**8**	**10**	**24**	**9**	**2**	**6**	**2**
186	64	19.97	166	6.81	107	1.00	11.6	7.6	5	2	13	4	1	10	7
186	**64**	19.99	**166**	**6.99**	**113**	**1.00**	**11.6**	**7.6**	**5**	**2**	**13**	**4**	**6**	**8**	**12**
187	64	19.25	166	28.57	322	1.00	13.6	na	6	0	12	0	0	0	0
200	64	29.96	161	53.77	53	1.00	5.2	12.8	0	0	0	0	0	0	0
202	64	29.70	163	51.02	72	1.02	7.7	10.2	0	0	0	0	0	0	0
203	64	29.98	164	11.76	284	1.00	9.9	9.6	0	0	0	0	0	0	0
205	64	26.49	166	7.81	72	0.90	18.2	8.3	0	0	0	0	0	0	0
220[j]	64	38.47	161	21.56	76	0.95	4.2	13.3	0	0	0	0	0	0	0

Note: Stations resurveyed due to ≥5 legal red king crabs caught are indicated in bold. Temperature logger was not functioning for the first day; therefore temperature was unavailable for some stations.

[a] Juvenile female red king crabs include all females that were non-ovigerous, had clean pleopodal setae, and had abdominal flaps that did not extend over the coxa.

[b] Adult female red king crabs include all ovigerous females and all non-ovigerous females with abdominal flaps that extended over the coxa.

[c] Prerecruit-3s include all sublegal male crabs <76 mm carapace length (CL).

[d] Prerecruit-2s include all sublegal male crabs 76 mm to 89 mm CL.

[e] Prerecruit ones include all sublegal male crabs >89 mm CL.

[f] Legal male red king crabs are ≥121 mm (4.75 in) carapace width, including lateral spines.

[g] Recruits are legal new-shell male crabs ≤115 mm CL.

[h] Postrecruits are legal new-shell male crabs >115 mm CL, and all old-shell legal crabs of legal width.

[i] Tow contained a large amount of mud.

[j] Significant net damage.

[k] Bad trawl (net was torn beyond use) the first time, so the station was retowed with a different net 2 days later.

Table 2.–Norton Sound trawl survey dates, gear type, total number of successful tows, total number of stations completed in the core and tiers 1-3, number of resampled stations, and sampling time schedule.

Year	Dates	Gear Type	Total Number of Successful Tows	Total Number of Stations Completed in Core & Tiers 1-3	Number of Resampled Stations	Sampling Time
1976	9/2-9/5, 9/16-10/6	83-112 Eastern Otter Trawl	192	na	17	24-Hour-Basis
1979	7/26-8/5	83-112 Eastern Otter Trawl	115	na	16	24-Hour-Basis
1982	9/5-9/11	83-112 Eastern Otter Trawl	53	na	0	24-Hour-Basis
1985	9/16-10/1	83-112 Eastern Otter Trawl	78	na	0	Daylight Hours
1988	8/16-8/30	83-112 Eastern Otter Trawl	82	na	4	24-Hour-Basis
1991	8/22-8/30	83-112 Eastern Otter Trawl	53	na	0	Daylight Hours
1996	8/7-8/18	400 Eastern Otter Trawl	69	48	21	Daylight Hours
1999	7/28-8/7	400 Eastern Otter Trawl	59	50	9	Daylight Hours
2002	7/27-8/6	400 Eastern Otter Trawl	60	56	3	Daylight Hours
2006	7/25-8/8	400 Eastern Otter Trawl	75	69	4	Daylight Hours
2008	7/24-8/11	400 Eastern Otter Trawl	68	67	2	Daylight Hours
2011	7/18-8/15	400 Eastern Otter Trawl	70	63	5	Daylight Hours

Table 3.–Standardized results from population assessment surveys for red king crabs in Norton Sound, 1976–2011.

				Number of Red King Crabs Captured[a,b]				Population Abundance Estimates[c]			Standard Error		
Year	Dates	Research Agency	Gear	Prerecruit-2 Males	Prerecruit-1 Males	Legal Males[d]	Females	Prerecruit-2 Males	Prerecruit-1 Males	Legal Males	Prerecruit-2 Males	Prerecruit-1 Males	Legal Males
1976	9/02 - 9/05, 9/16 - 10/07	NMFS	Trawl	58(38)	110(213)	180(614)	101(35)	331,555	808,091	1,742,755	44,653	70,094	104,941
1979[e]	7/26 - 8/05	NMFS	Trawl	N/A	N/A	90(86)	N/A			809,799			61,176
1980[f]	7/04 - 7/14	ADF&G	Pots			3,290	158			1,900,000			
1981	6/28 - 7/14	ADF&G	Pots			3,415	1,933			1,285,195			
1982	7/06 - 7/20	ADF&G	Pots			2,001	424			353,273			
1982	9/05 - 9/11	NMFS	Trawl	42	107	97	256	356,724	832,581	877,722	50,116	76,454	79,907
1985	7/01 - 7/14	ADF&G	Pots			4,645	181			907,579			
1985	9/16 - 10/1	NMFS	Trawl	63	94	139	139	466,858	707,140	1,051,857	58,598	71,999	87,931
1988	8/16 - 8/30	NMFS	Trawl	82(0)	69(1)	135(3)	212(2)	565,255	493,030	978,748	62,339	58,224	82,083
1991	8/22 - 8/30	NMFS	Trawl	39	42	166	105	294,801	303,682	1,287,486	46,648	46,960	98,101
1996	8/07 - 8/18	ADF&G	Trawl	39(36)	32(17)	53(14)	98(70)	452,580	325,699	536,235	52,324	47,338	69,647
1999	7/28 - 8/07	ADF&G	Trawl	9(3)	64(38)	103(63)	64(18)	103,832	940,198	1,594,341	40,841	120,449	129,864
2002	7/27 - 8/06	ADF&G	Trawl	34(18)	42(23)	61(29)	116(35)	427,703	518,638	771,569	73,494	80,741	85,303
2006	7/25 - 8/08	ADF&G	Trawl	77(3)	37(16)	51(18)	66(1)	775,076	569,833	726,251	91,812	82,883	92,590
2008	7/24 - 8/11	ADF&G	Trawl	51(18)	46(19)	53(15)	90(2)	795,777	697,442	811,727	100,778	91,542	103,155
2011	7/18 - 8/15	ADF&G	Trawl	25(15)	19(10)	84(39)	98(25)	431,153	311,550	1,310,634	150,806	87,634	126,017

[a] Number of crabs captured on ADF&G pot surveys represent data standardized for a 24-hour soak.

[b] For the 1976, 1979, 1988, and all ADF&G trawl catches, the numbers outside of parentheses exclude catch from resampled stations. The numbers in parentheses represent catch from resampled stations. The 1979, 1996, 2006, and 2008 population estimates incorporated resampled stations by combining catches and tow distances for each station resampled.

[c] Population estimates are valid for the date of the survey (i.e., either before or after the summer commercial fishery).

[d] Legal male red king crabs were defined as ≥ 121 mm (4.75 in) in carapace width (CW) for the pot surveys and all ADF&G trawl surveys, and ≥ 104 mm CL for all of the NMFS trawl surveys except the 1979 survey which defined legal males as ≥ 100 mm CL.

[e] Prerecruit-1 and prerecruit-2 male, and female data are not available for the 1979 NMFS trawl survey and the legal male abundance estimate is fully standardized.

[f] The 1980 pot survey estimate has been revised from the original estimate of 13.4 million pounds which was thought inaccurate due to an under-reporting of recovered tagged crabs.

Table 4.–Length frequency and percent ovigerity of female red king crabs captured during the 2011 Norton Sound trawl survey.

Carapace	Adult Percent Ovigerity					Total	Juveniles	
Length (mm)	0%	1-29%	30-59%	60-89%	90-100%	Adults	(Immature)	All Females
20	0	0	0	0	0	0	1	1
33	0	0	0	0	0	0	2	2
34	0	0	0	0	0	0	2	2
36	0	0	0	0	0	0	1	1
39	0	0	0	0	0	0	1	1
41	0	0	0	0	0	0	2	2
45	0	0	0	0	0	0	2	2
46	0	0	0	0	0	0	2	2
48	0	0	0	0	0	0	2	2
49	0	0	0	0	0	0	1	1
50	0	0	0	0	0	0	3	3
53	0	0	0	0	0	0	2	2
54	0	0	0	0	0	0	6	6
55	0	0	0	0	0	0	1	1
56	0	0	0	0	0	0	1	1
57	0	0	0	0	0	0	1	1
58	0	0	0	0	0	0	3	3
59	0	0	0	0	0	0	5	5
60	0	0	0	0	0	0	5	5
61	0	0	0	0	0	0	4	4
62	0	0	0	0	0	0	8	8
63	0	0	0	0	0	0	4	4
64	0	0	0	0	0	0	5	5
65	0	0	1	0	0	1	3	4
66	0	0	0	0	0	0	3	3
67	0	0	0	0	0	0	1	1
68	1	0	0	0	0	1	1	2
69	1	0	1	0	0	2	1	3
70	1	0	0	1	0	2	1	3
71	0	0	3	1	0	4	0	4
72	0	0	1	1	0	2	0	2
73	1	0	0	1	0	2	0	2
74	1	0	1	2	0	4	0	4
75	0	1	2	0	0	3	0	3
76	0	0	0	1	0	1	0	1
77	0	0	4	0	0	4	0	4
78	0	0	1	4	1	6	0	6
80	0	0	1	0	0	1	0	1
81	0	0	0	2	1	3	0	3
83	0	0	1	0	1	2	0	2
84	1	0	0	0	1	2	0	2
85	0	0	0	1	0	1	0	1
86	0	0	0	1	0	1	0	1
87	0	0	0	2	1	3	0	3
88	0	0	0	0	1	1	0	1
89	0	0	0	1	1	2	0	2
90	0	0	0	2	0	2	0	2

-continued-

Table 4.–Page 2 of 2.

Carapace	Adult Percent Ovigerity					Total	Juveniles	
Length (mm)	0%	1-29%	30-59%	60-89%	90-100%	Adults	(Immature)	All Females
91	0	0	0	0	1	1	0	1
92	0	0	0	1	0	1	0	1
94	0	1	0	0	0	1	0	1
95	0	0	0	1	0	1	0	1
98	0	0	1	0	1	2	0	2
99	0	0	0	2	0	2	0	2
100	0	0	0	1	0	1	0	1
101	0	0	0	0	1	1	0	1
110	0	0	0	1	0	1	0	1
Total	6	2	17	26	10	61	74	135

Table 5.–The top 40 taxa, ranked by CPUE, identified during the 2011 ADF&G Norton Sound red king crab trawl survey.

Rank	NMFS Species Code	Common Name	Scientific Name or Taxon	CPUE (kg/km^2)
1	81742	Purple-orange sea star	*Asterias amurensis*	296,406
2	80200	Black-spined sea star	*Lethasterias nanimensis*	37,396
3	21735	Saffron cod	*Eleginus gracilis*	30,057
4	10220	Starry flounder	*Platichthys stellatus*	30,037
5	91000	Sponge unidentified	*Porifera sp.*	19,068
6	80020	Giant sea star	*Evasterias echinosoma*	17,531
7	10210	Yellowfin sole	*Limanda aspera*	12,845
8	21375	Myoxocephalus unidentified	*Myoxocephalus sp.*	12,291
9	82510	Green sea urchin	*Strongylocentrotus droebachiensis*	11,717
10	10285	Alaska plaice	*Pleuronectes quadrituberculatus*	11,453
11	69322	Red king crab	*Paralithodes camtschaticus*	9,670
12	43000	Sea anemone unidentified	*Actinaria sp.*	9,316
13	68781	Helmet crab	*Telmessus cheiragonus*	9,222
14	40500	Jellyfish unidentified	*Scyphozoa sp.*	9,095
15	69120	Hairy hermit crab	*Pagurus capillatus*	8,895
16	21110	Pacific herring	*Clupea pallasi*	6,994
17	71884	Northern neptune	*Neptunea heros*	6,797
18	98082	Sea potato	*Styela rustica*	6,756
19	80595	Leptasterias unidentified	*Leptasterias sp.*	6,736
20	98000	Tunicate unidentified	*Ascidiacea sp.*	5,149
21	68580	Opilio crab	*Chionoecetes opilio*	4,852
22	10120	Pacific halibut	*Hippoglossus stenolepis*	4,402
23	69086	Fuzzy hermit crab	*Pagurus trigonocheirus*	4,035
24	83020	Basket sea star	*Gorgonocephalus eucnemis*	3,841
25	68577	Circumboreal toad crab	*Hyas coarctatus*	3,517
26	80590	Knobby 6-rayed sea star	*Leptasterias polaris*	2,342
27	23055	Rainbow smelt	*Osmerus mordax*	2,038
28	23801	Lumpenus unidentified	*Lumpenus sp.*	1,881
29	98300	Compound ascidian unidentified	*Ascidian sp.*	1,844
30	21388	Antlered sculpin	*Enophrys diceraus*	1,689
31	41201	Sea raspberry	*Gersemia sp.*	1,534
32	95000	Bryozoan unidentified	*Bryozoa*	1,531
33	66580	Arctic argid	*Argis dentata*	1,426
34	71882	Fat whelk	*Neptunea ventricosa*	1,167
35	75284	Serripes unidentified	*Serripes sp.*	1,117
36	10155	Arctic flounder	*Liopsetta glacialis*	1,103
37	24189	Polar eelpout	*Lycodes turneri*	1,100
38	65100	Barnacle unidentifed	*Thoracica sp.*	893
39	74562	Discordant mussel	*Musculus discors*	888
40	71001	Snail eggs unidentified	*Gastropod* eggs	668

Table 6.–Data on large fish collected during the ADF&G Norton Sound red king crab trawl survey for 2002, 2006, 2008, and 2011.

Year	# of Stations Sampled	Species	# of Fish Sampled	Average Length (mm)	Average Weight (kg)
2002	60	Pacific Halibut	10	750	7.4
		Pacific Cod	27	650	3.2
		Walleye Pollock	38	730	2.7
2006	75	Pacific Halibut	28	702	5.1
		Pacific Cod	17	754	4.1
		Walleye Pollock	27	698	3.1
2008	68	Pacific Halibut	27	692	4.9
		Pacific Cod	30	696	4.7
		Walleye Pollock	11	736	2.8
2011	70	Pacific Halibut	19	700	5.4
		Pacific Cod	1	896	7.2
		Yellowfin Sole	1	440	1.6

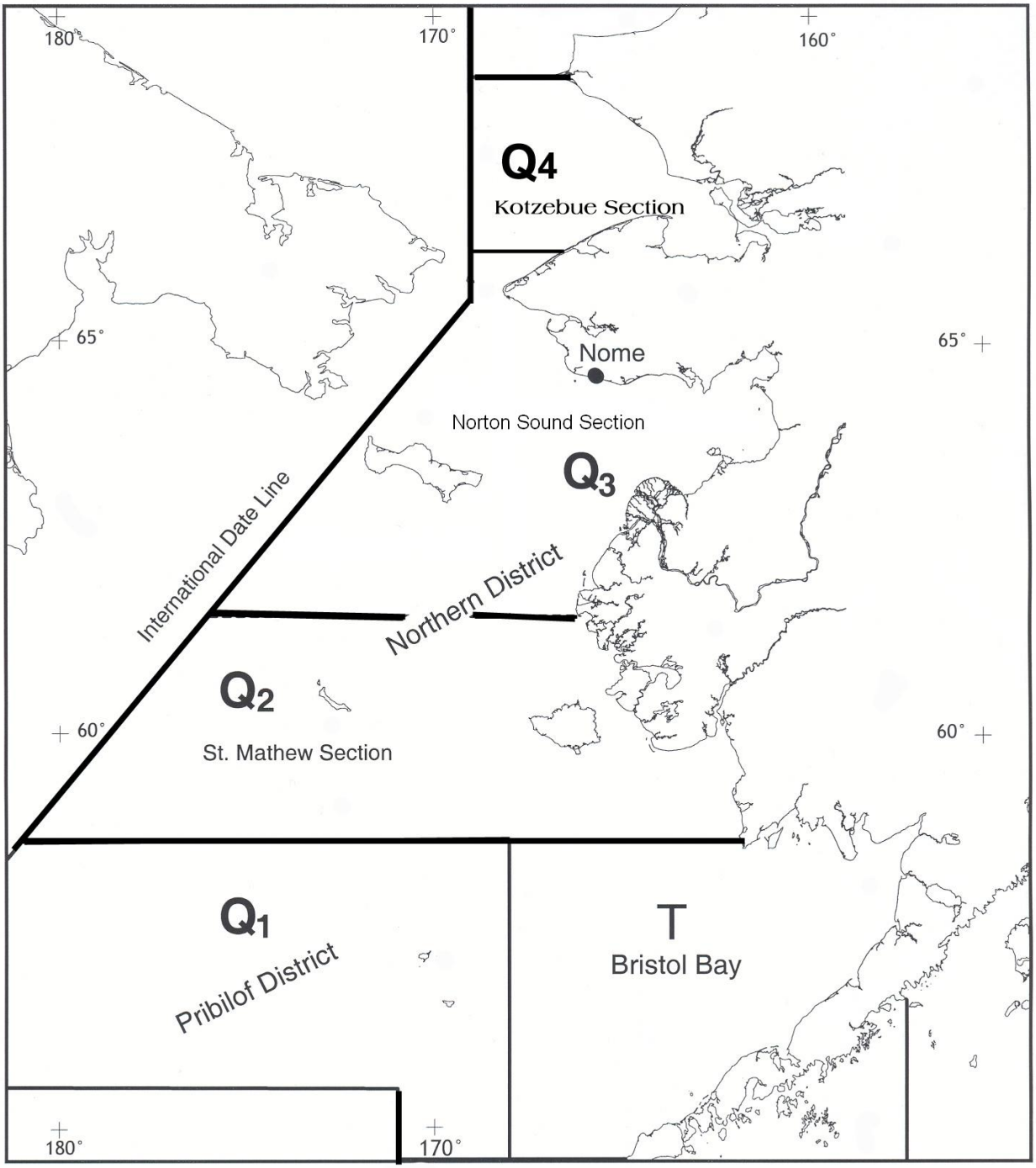

Figure 1.–King crab fishing districts and sections of Registration Area Q.

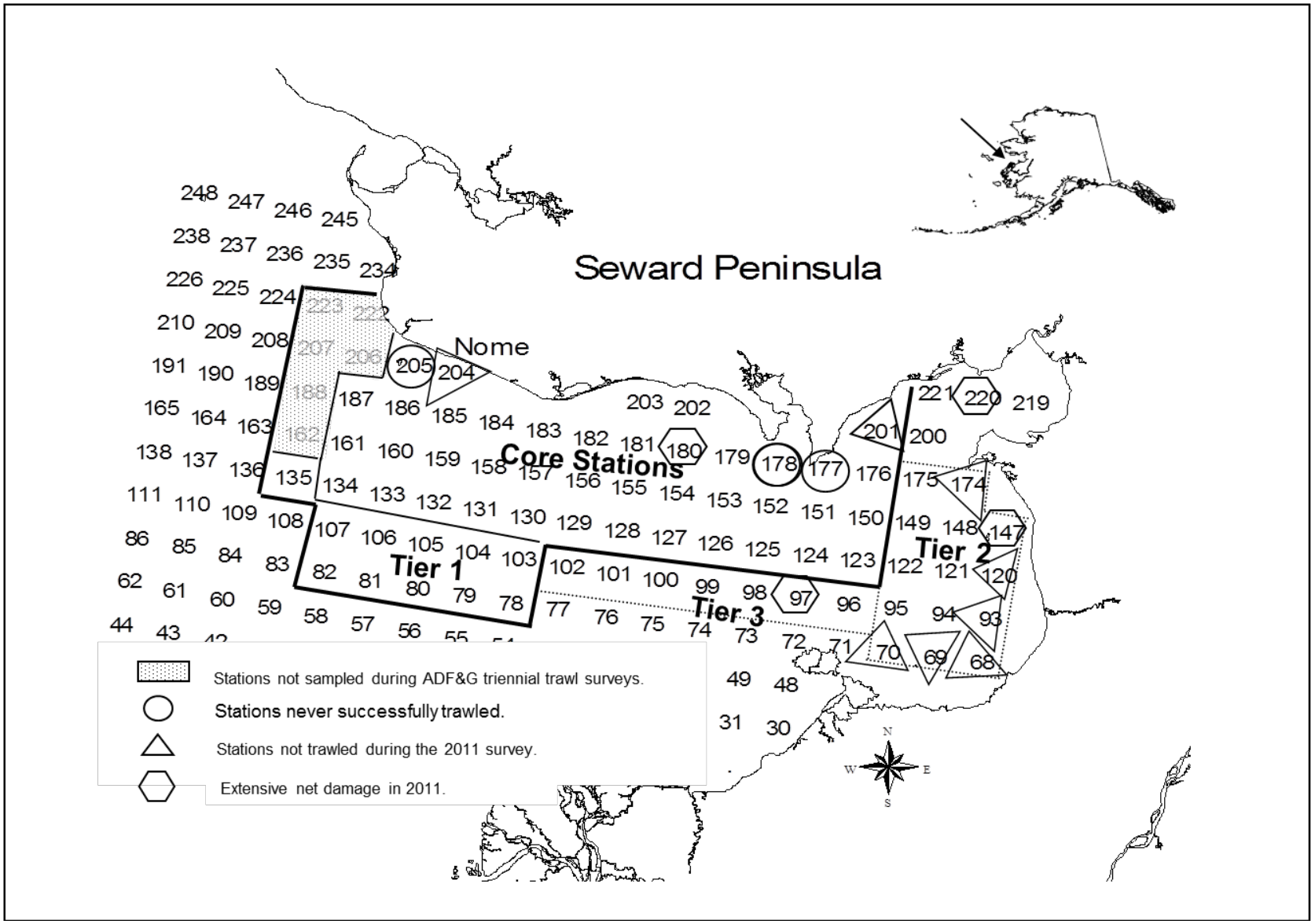

Figure 2.–Station identification numbers for the 2011 ADF&G Norton Sound trawl survey.

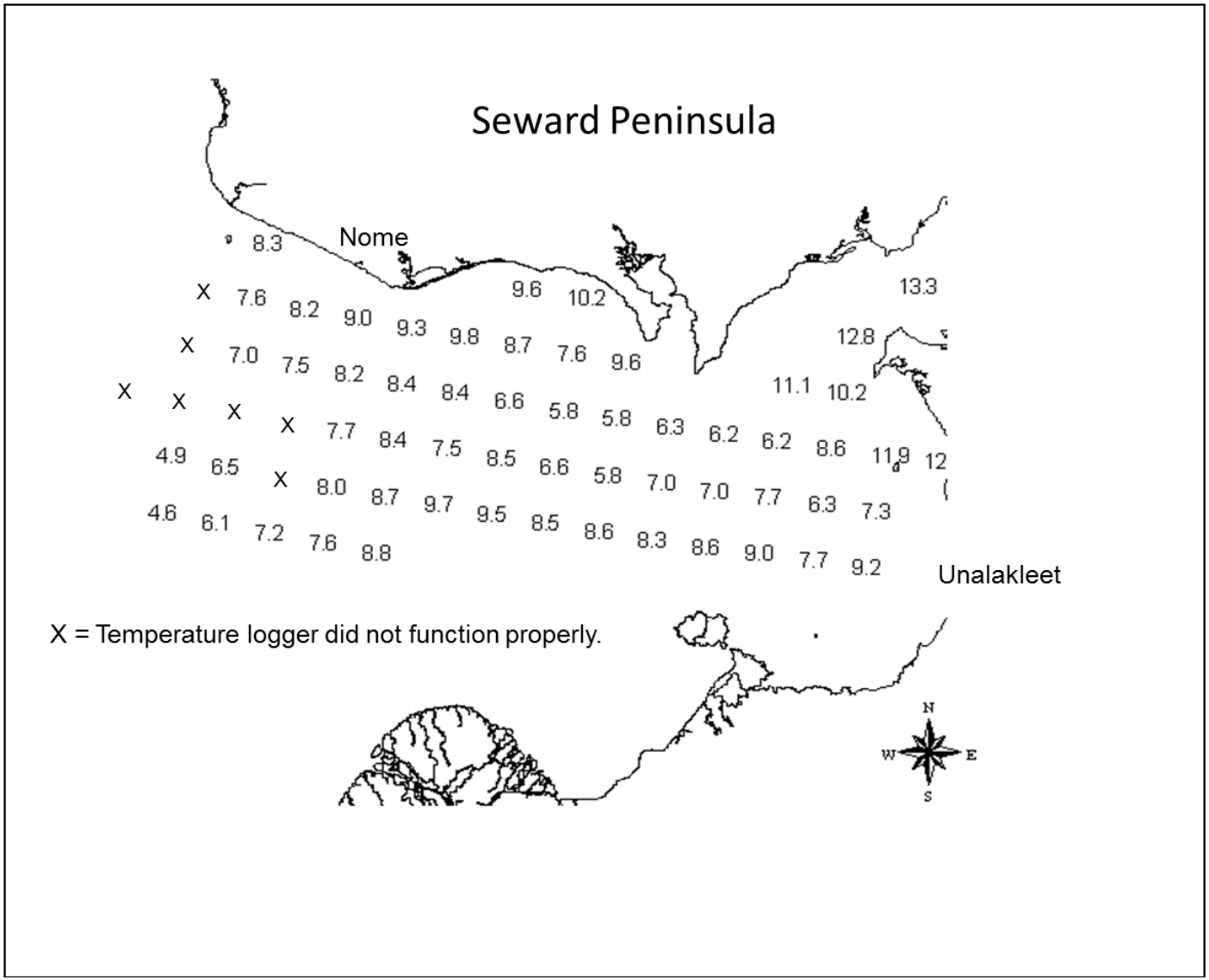

Figure 3.–Mean bottom temperatures (˚C) from the 2011 ADF&G Norton Sound trawl survey.

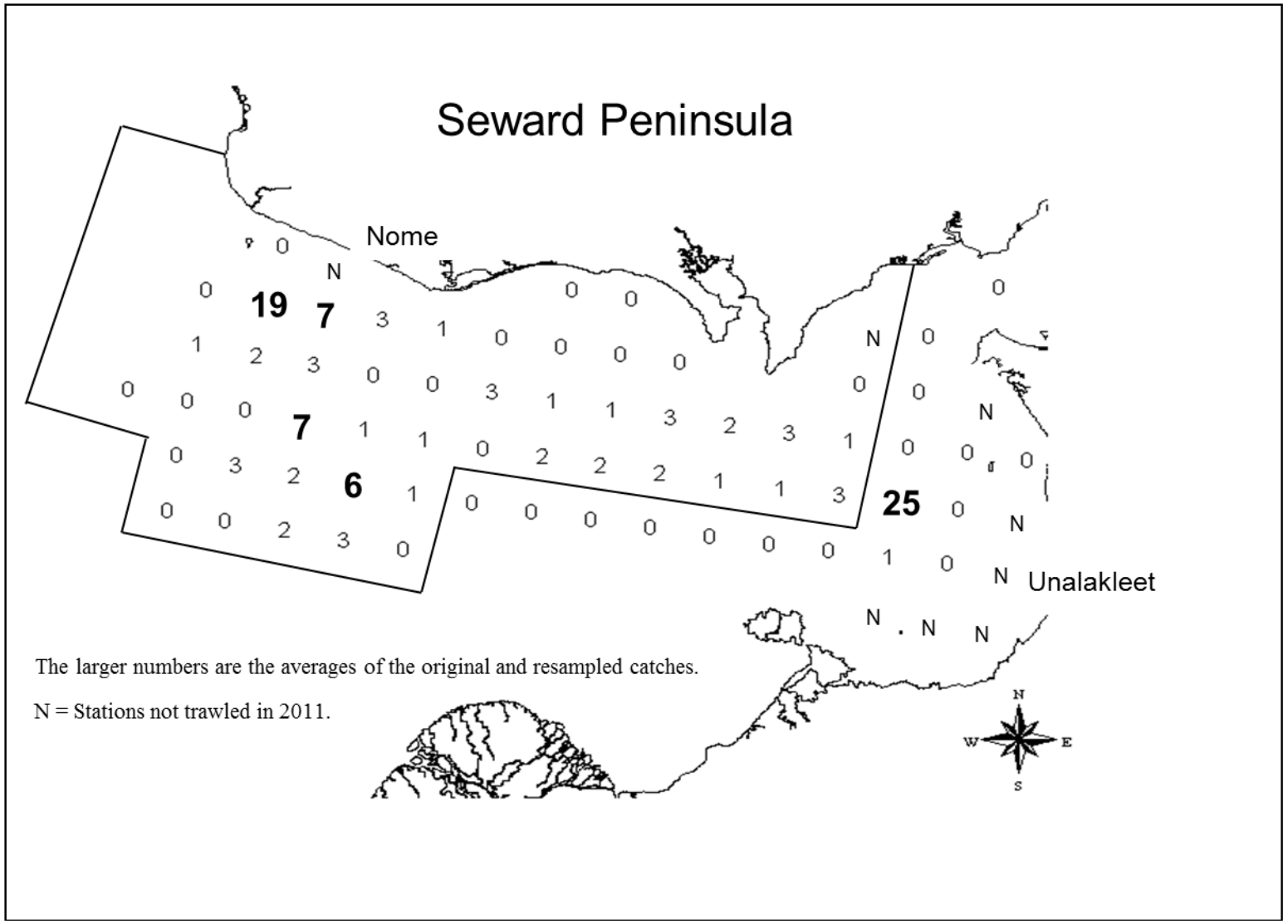

Figure 4.–Legal male red king crab catches from the 2011 ADF&G Norton Sound trawl survey.

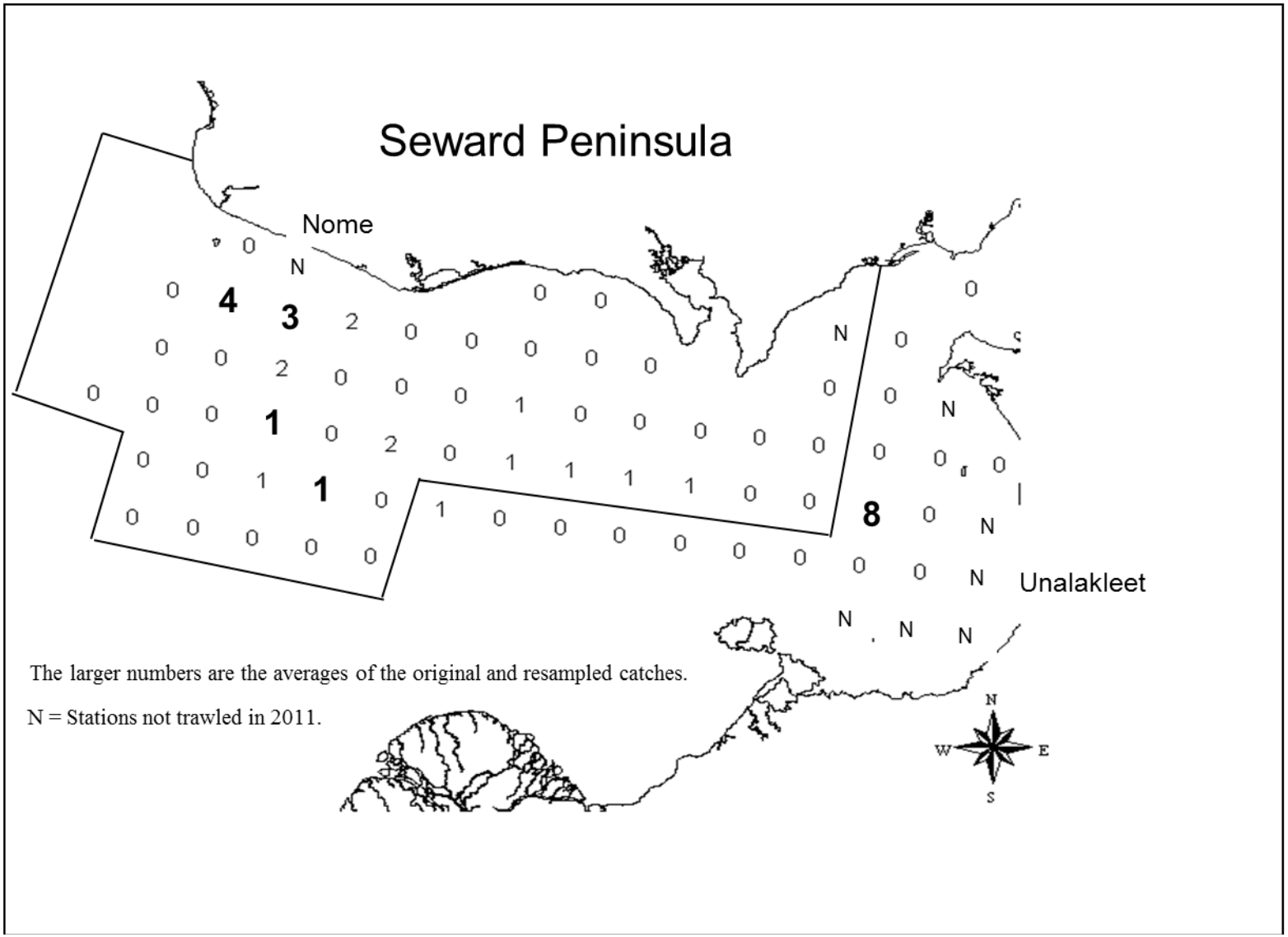

Figure 5.–Prerecruit-1 male red king crab catches from the 2011 ADF&G Norton Sound trawl survey.

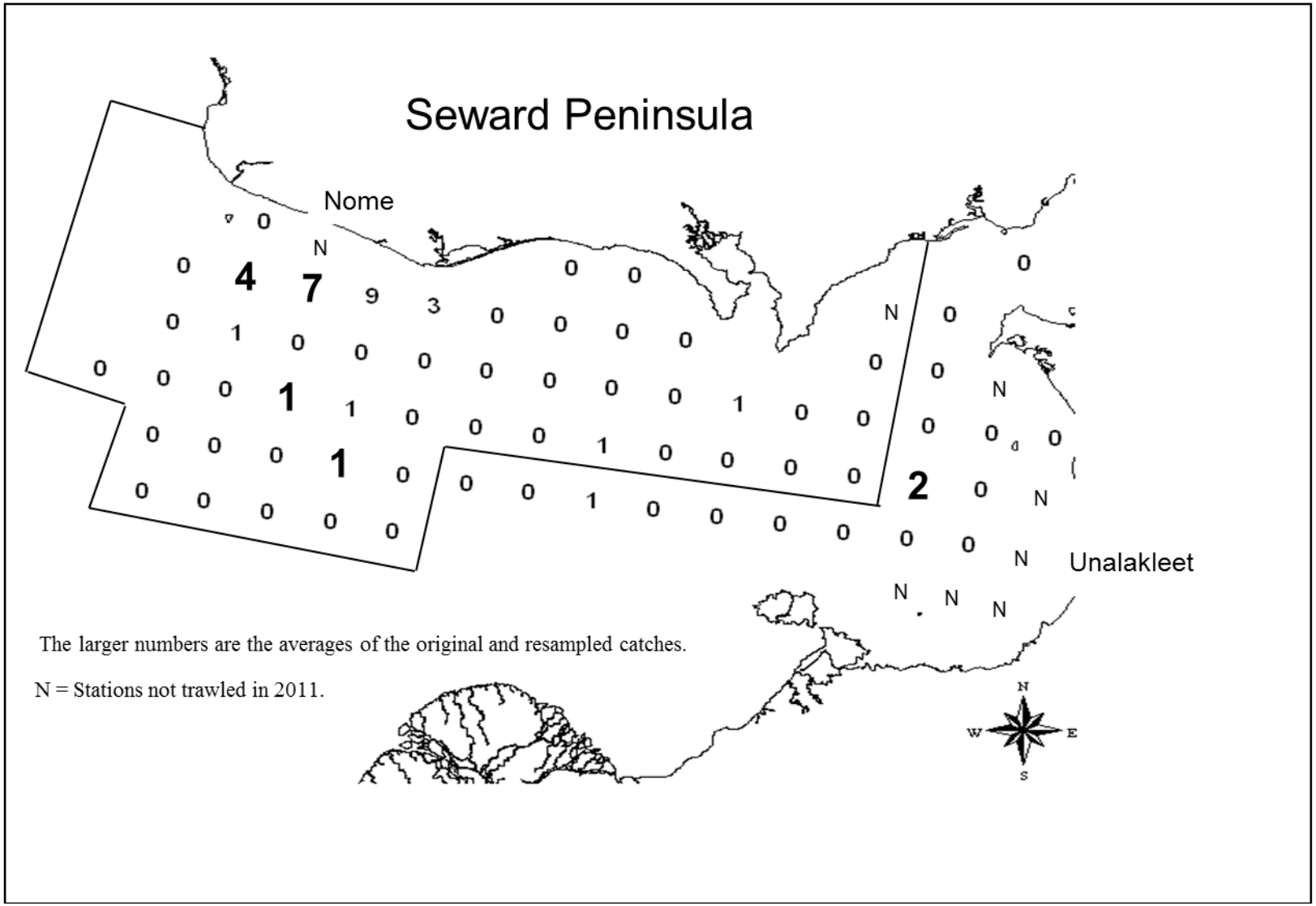

Figure 6.–Prerecruit-2 male red king crab catches from the 2011ADF&G Norton Sound trawl survey.

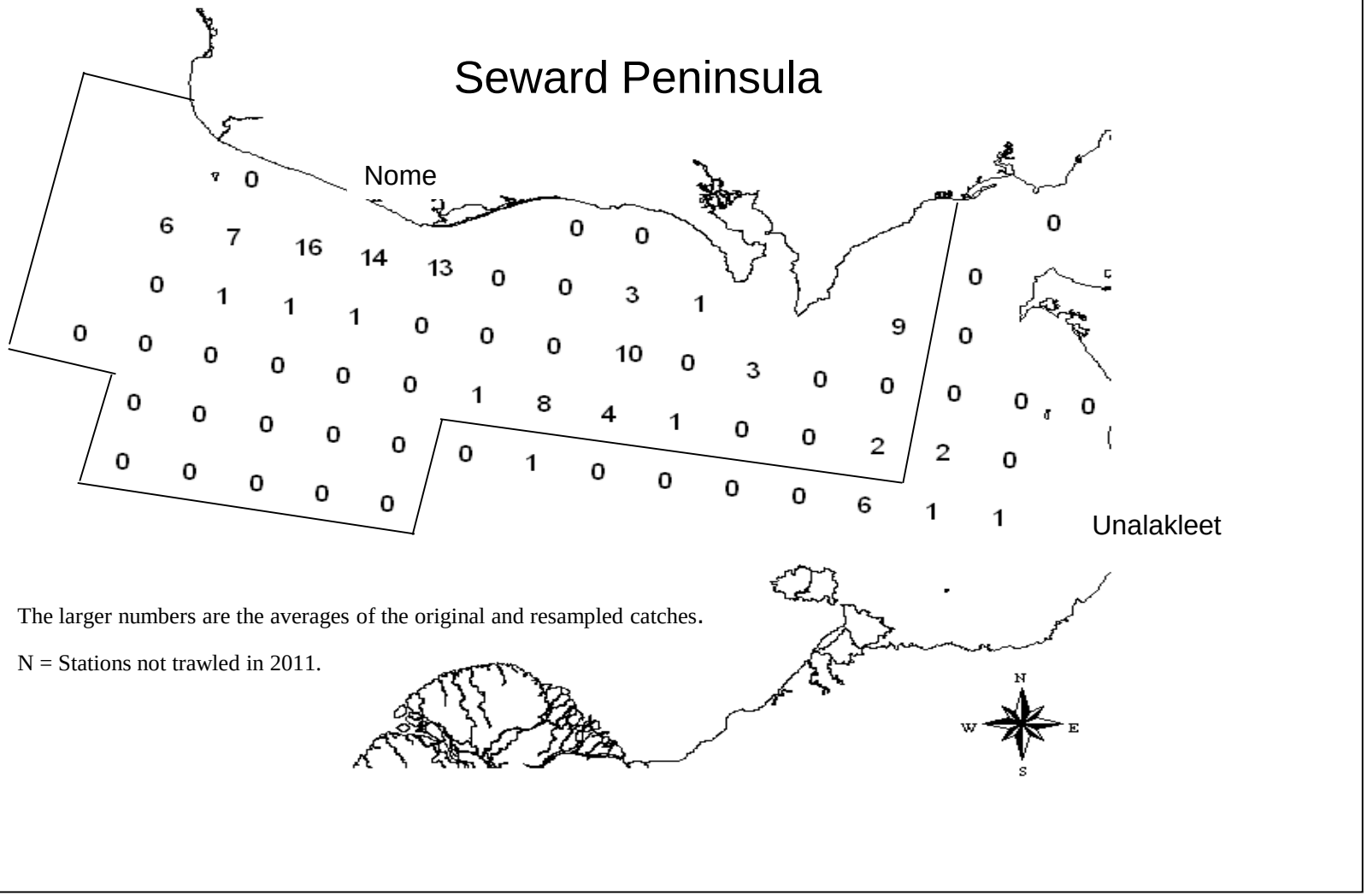

Figure 7.–Female red king crab catches from the 2011 ADF&G Norton Sound trawl survey.

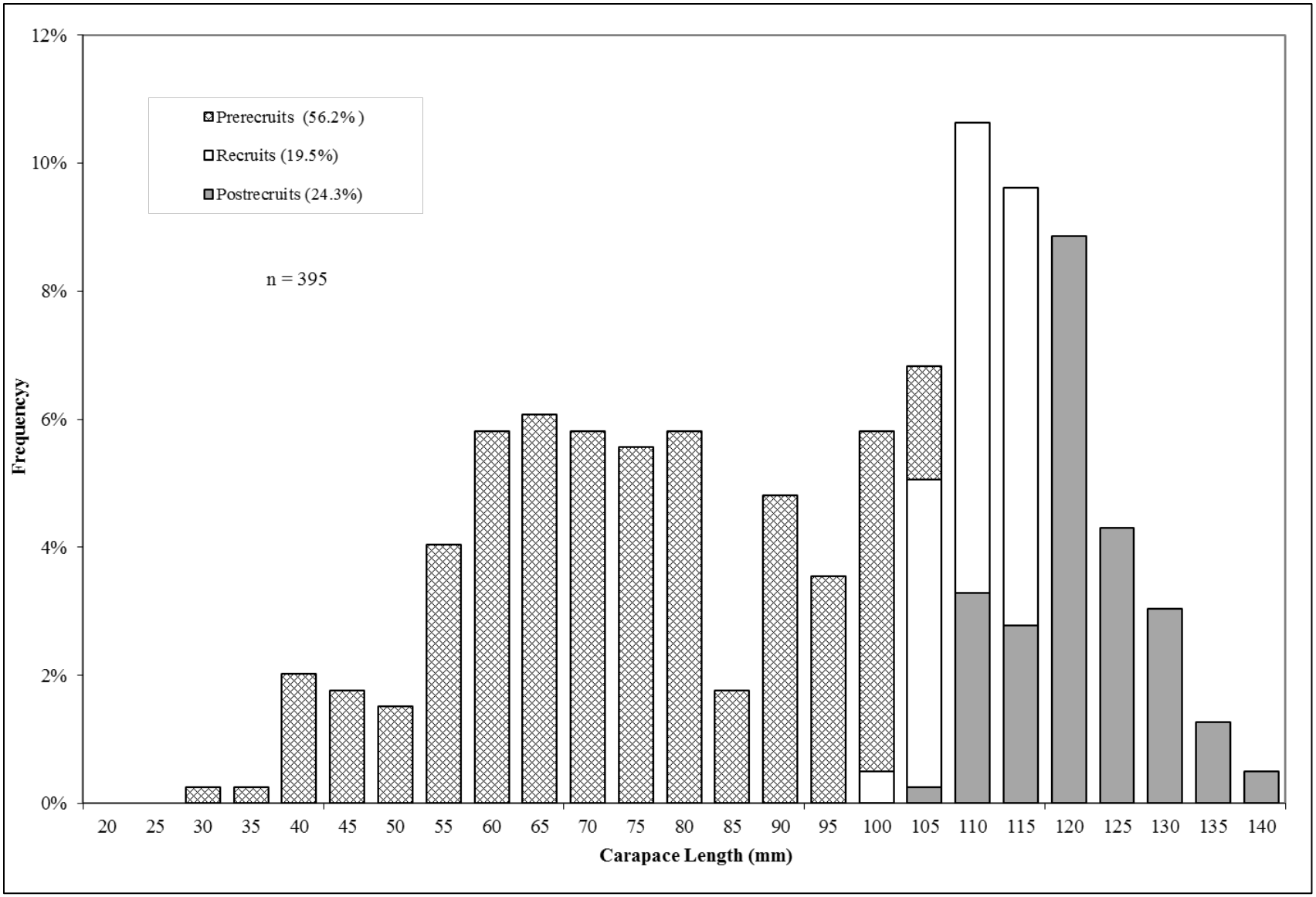

Figure 8.–Size composition of male red king crabs measured at standard and nonstandard stations during the 2011 ADF&G Norton Sound trawl survey.

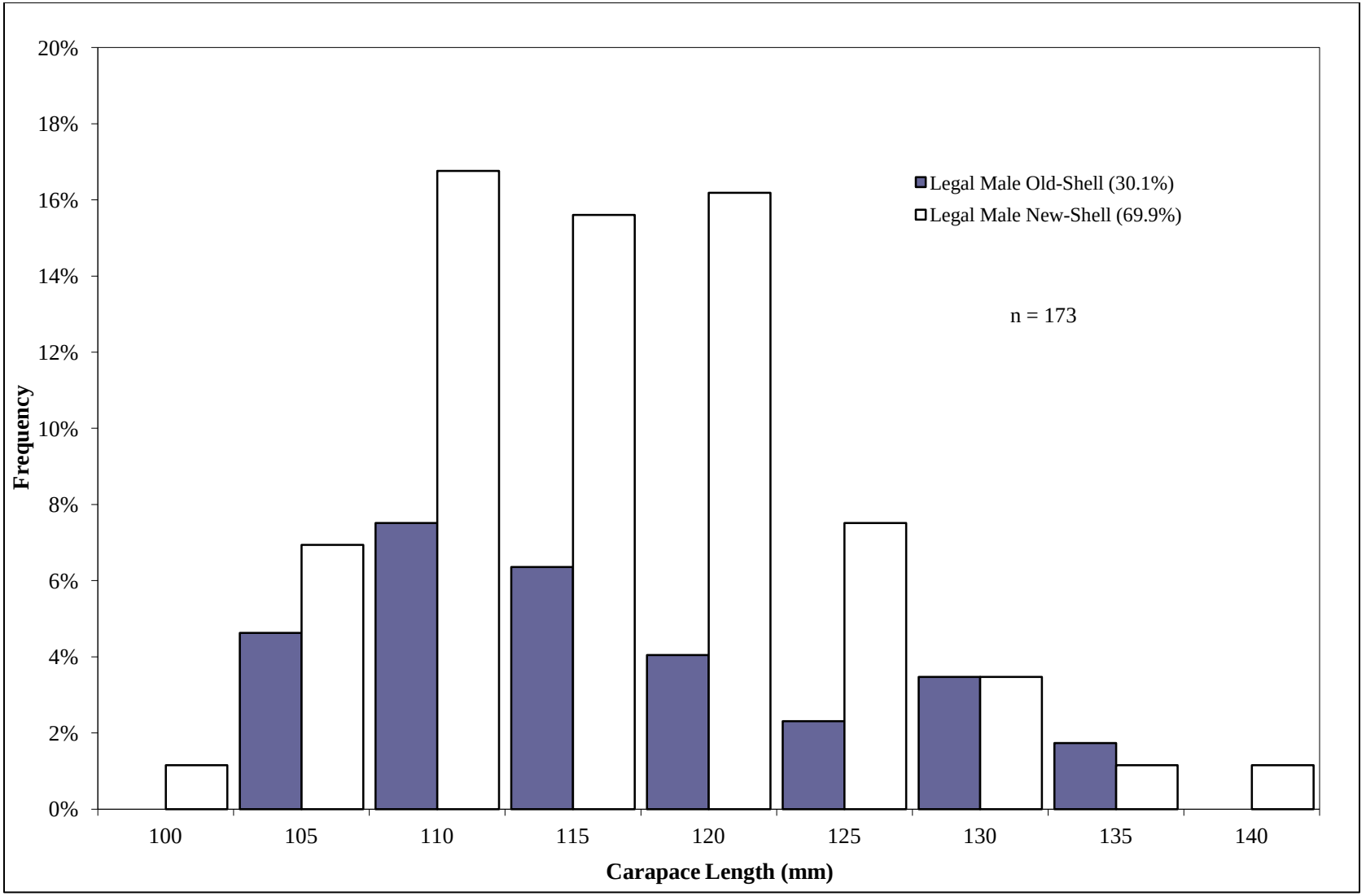

Figure 9.–Size composition by shell age of legal male red king crabs captured at standard and nonstandard stations during the 2011 ADF&G Norton Sound red king crab trawl survey.

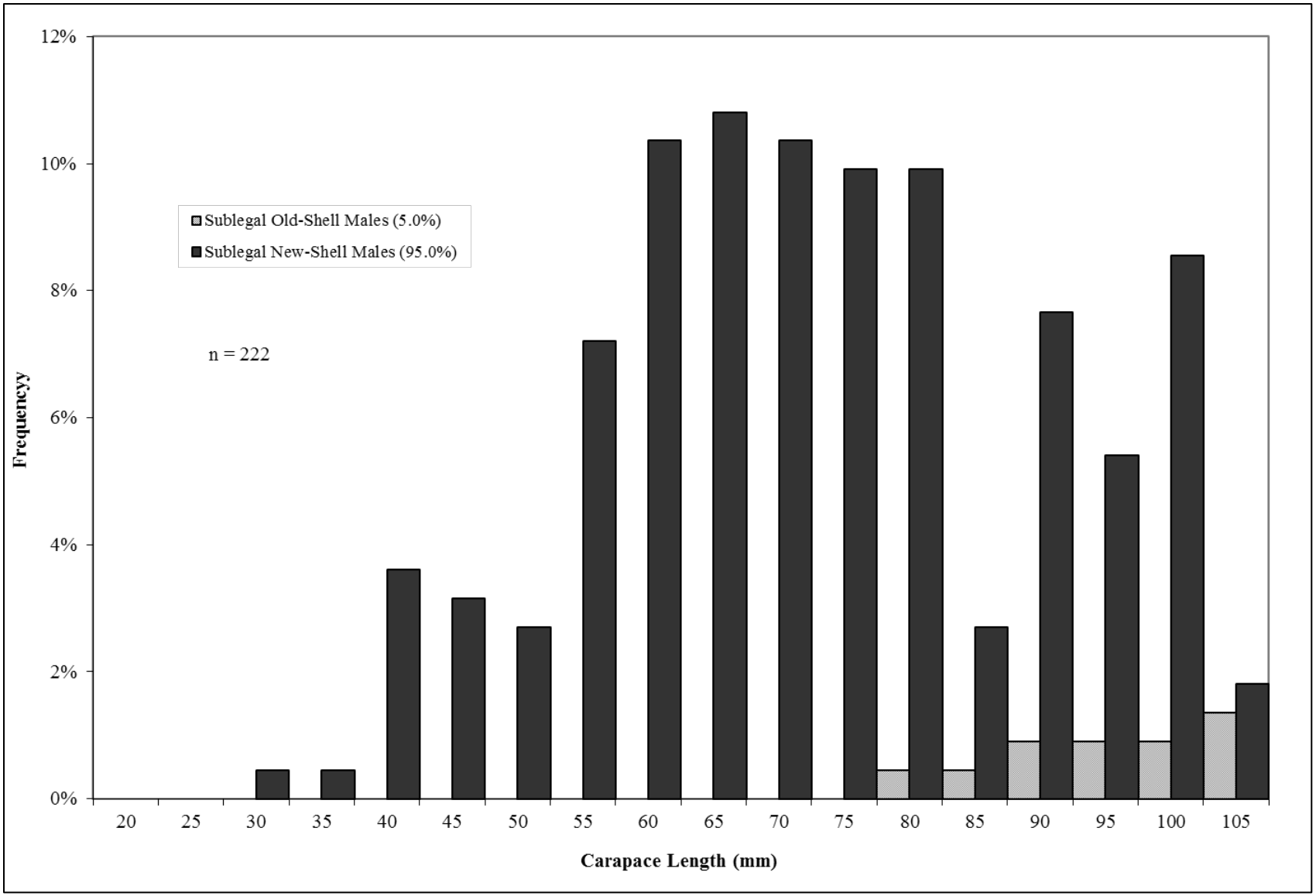

Figure 10.–Size composition by shell age of sublegal male red king crabs captured at standard and nonstandard stations during the 2011 ADF&G Norton Sound red king crab trawl survey.

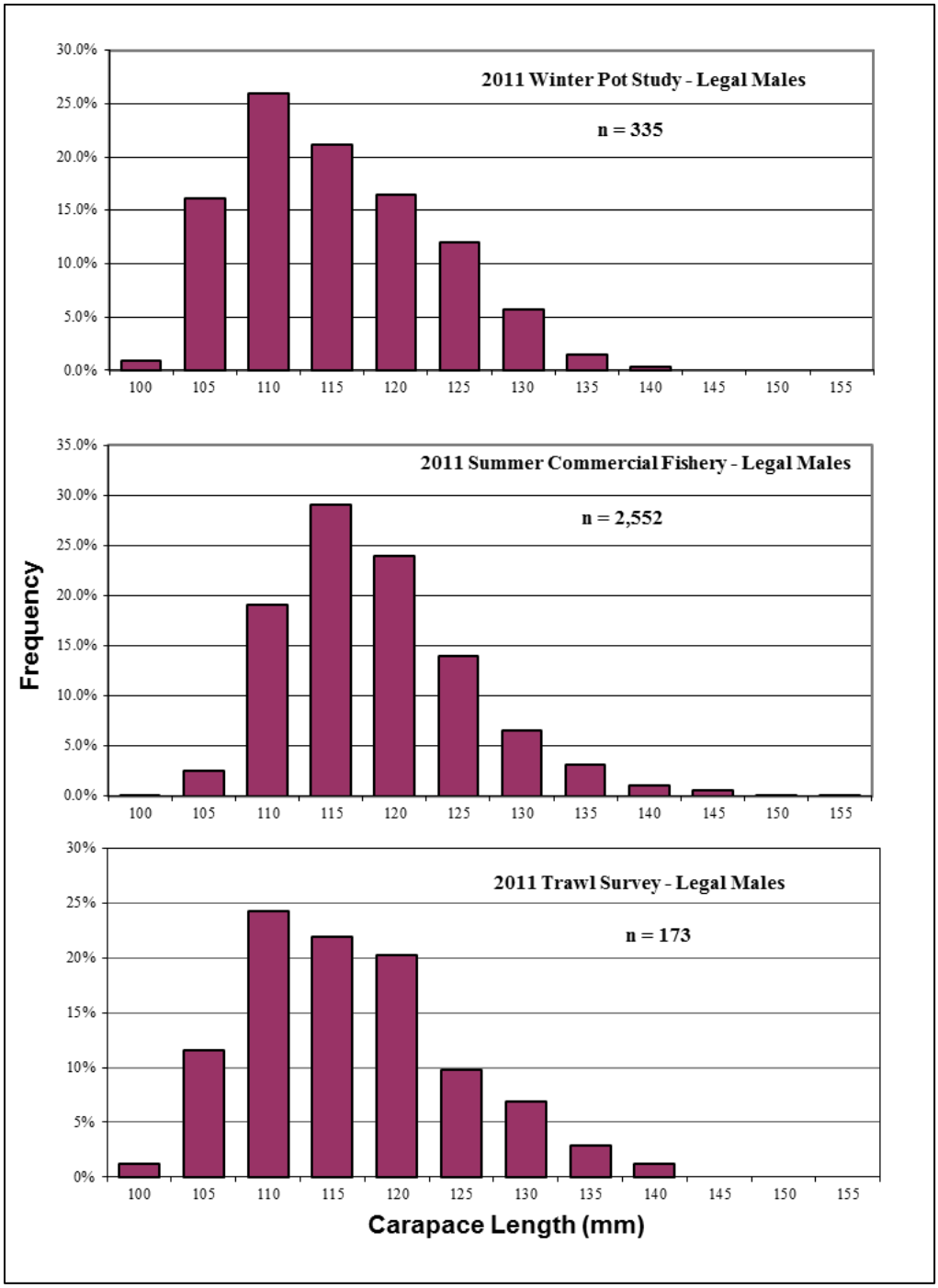

Figure 11.–Norton Sound legal male red king crab size compositions from the 2011 winter pot study (top), 2011 summer commercial fishery (middle), and 2011 ADF&G trawl survey (bottom).

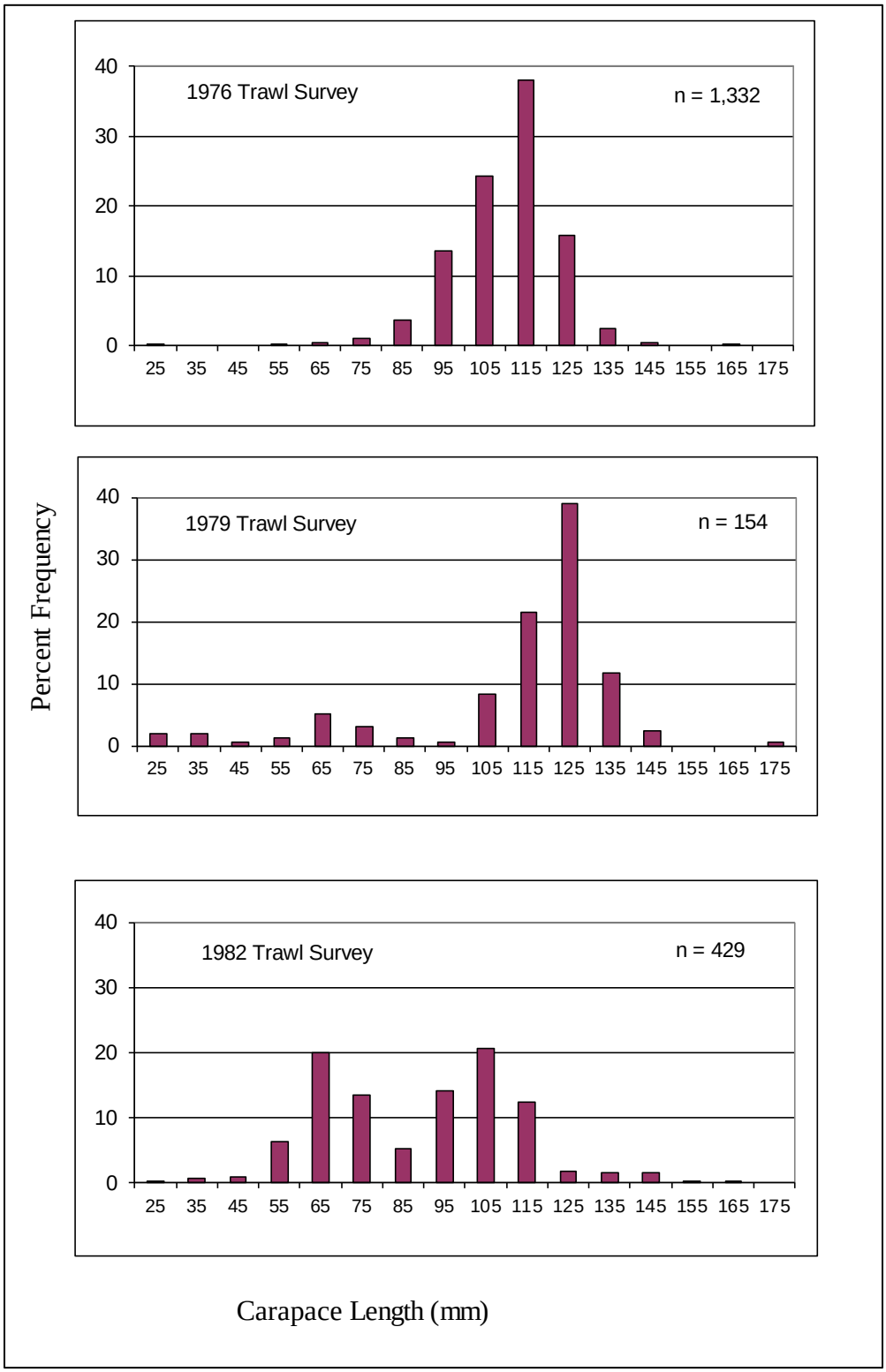

Figure 12.–Norton Sound size compositions for male red king crabs captured at standard and nonstandard stations during the 1976–2011 trawl surveys.

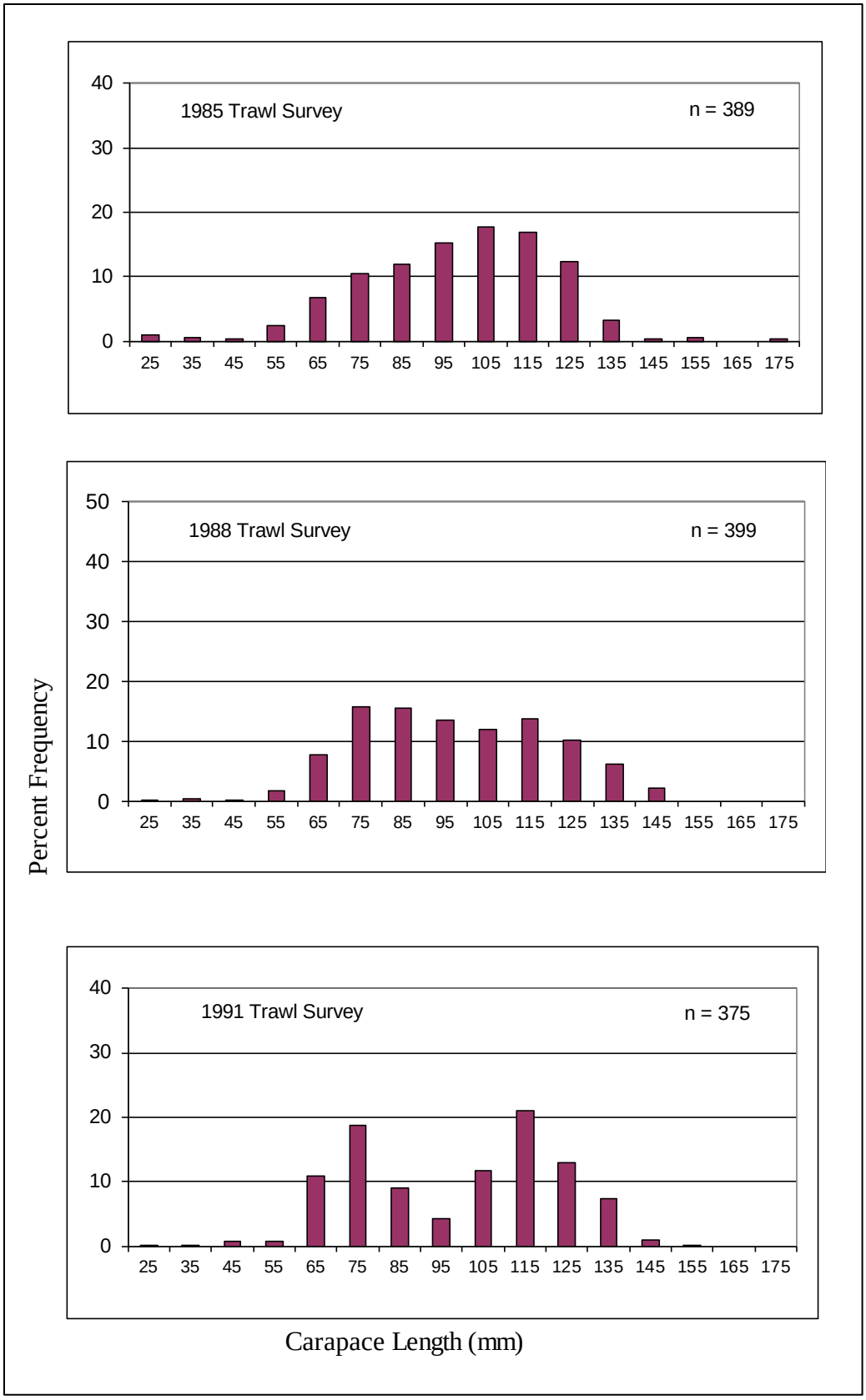

Figure 12.–Page 2 of 4.

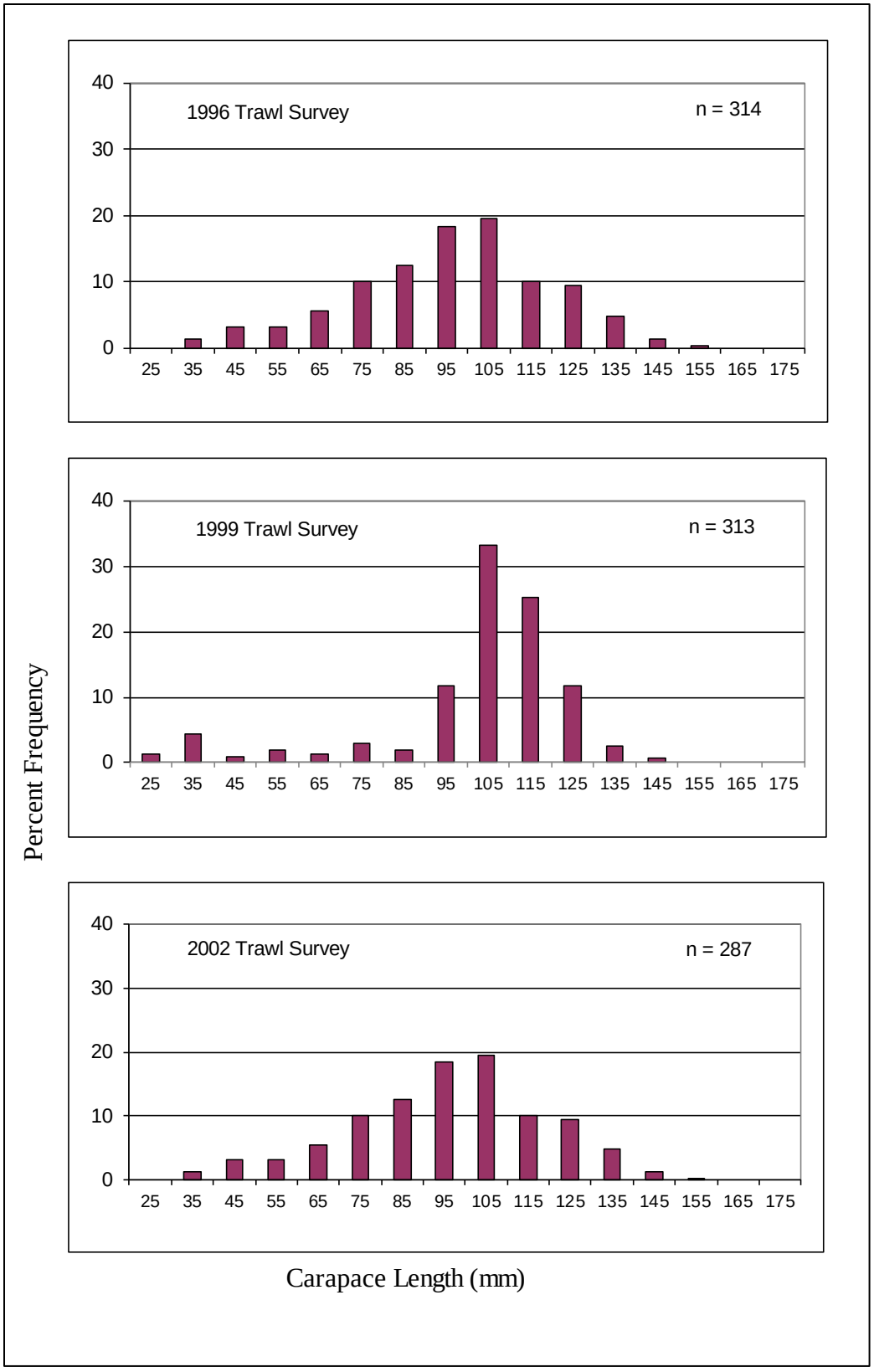

Figure 12.–Page 3 of 4.

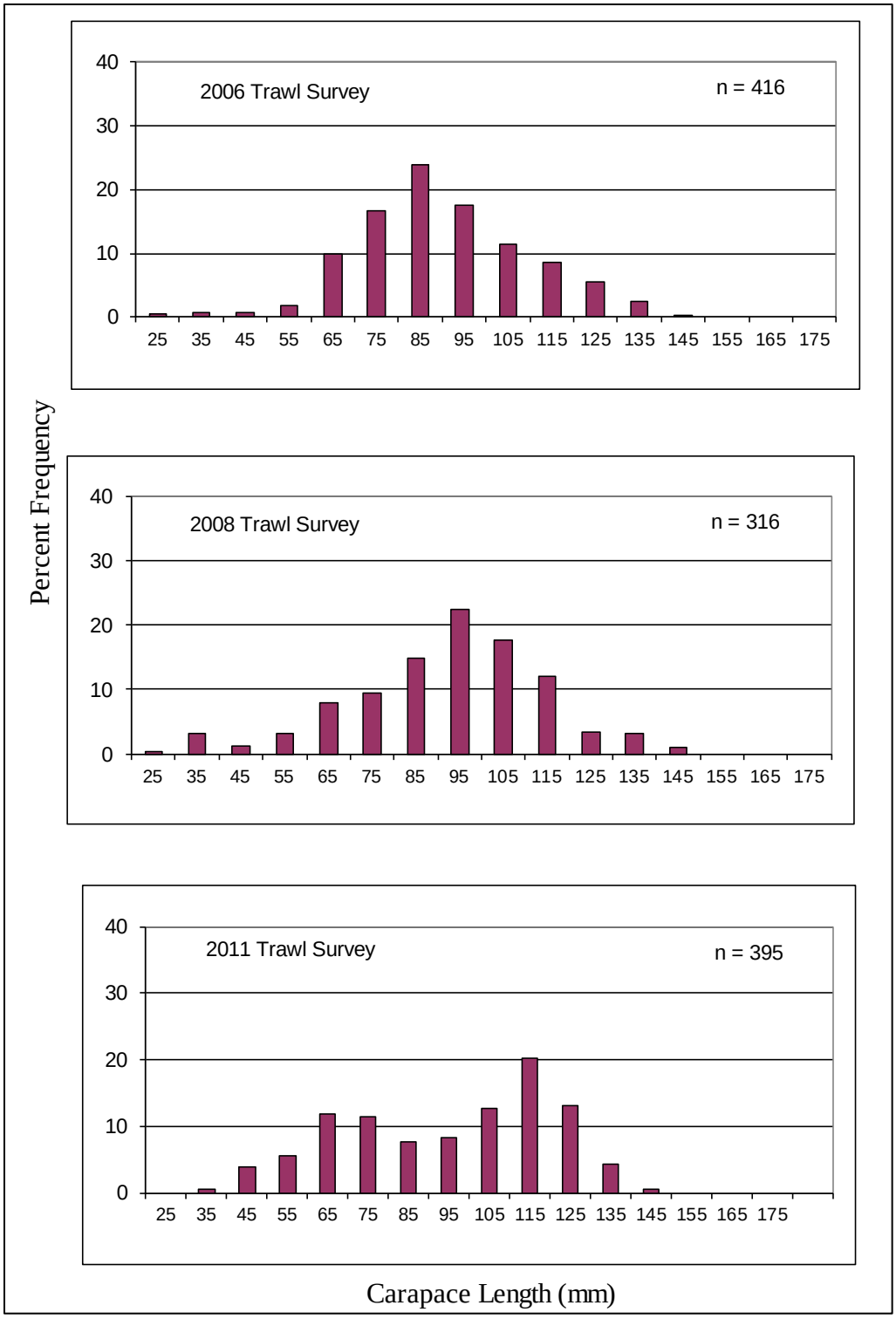

Figure 12.–Page 4 of 4.

APPENDIX A

Appendix A1.–Norton Sound ADF&G trawl survey data for standard and nonstandard stations that produced any legal male crab catch during the original survey and any resurveys, 2011.

Original Survey					Resurvey				
Station Number	No. of Legal Crabs	Area Trawled (sq. miles)	Total Area (sq. miles)	Estimated Abundance	Station Number	No. of Legal Crabs	Area Trawled (sq. miles)	Total Area (sq. miles)	Estimated Abundance
79	3	.0065800	100	45,593					
80	2	.0065800	100	30,395					
95	1	.0056588	100	17,672					
103	1	.0065800	100	15,198					
104	6	.0065800	100	91,185	104	5	.0065800	100	75,988
105	2	.0065800	100	30,395					
106	3	.0065800	100	45,593					
122	32	.0065800	100	486,322	122	17	.0065800	100	258,359
123	3	.0065800	100	45,593					
124	1	.0065800	100	15,198					
125	1	.0065800	100	15,198					
126	2	.0065800	100	30,395					
127	2	.0065800	100	30,395					
128	2	.0065800	100	30,395					
130	1	.0065800	100	15,198					
131	1	.0065800	100	15,198					
132	7	.0065800	100	106,383	132	6	.0065800	100	91,185
150	1	.0065800	100	15,198					
151	3	.0065800	100	45,593					
152	2	.0048034	100	41,637					
153	3	.0065800	100	45,593					
154	1	.0065800	100	15,198					
155	1	.0065800	100	15,198					
156	3	.0065800	100	45,593					
159	3	.0065800	100	45,593					
160	2	.0065800	100	30,395					
161	1	.0065800	100	15,198					
183	1	.0065800	100	15,198					
184	3	.0065800	100	45,593					
185	6	.0065800	100	91,185	185	8	.0065800	100	121,581
186	17	.0065800	100	258,359	186	20	.0065800	100	303,951